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Regional programming models for agricultural development planning in India

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TABLE OF CONTENTS

		Page
I.	INTRODUCTION	1
II.	INDIAN FIVE YEAR PLANS	6
	Outlay and Investment	8
	Distribution of the Outlay in the Public Sector	10
	Selected Indicators of Growth	10
	Agriculture	15
	Instruments for Increasing Agricultural Production	19
	Land reform	19
	Technical	21
	Irrigation	21
	Soil conservation, dry farming and land reclamation	24
	Fertilizers and manures	25
	Seed multiplication and distribution	26
	Plant protection	26
	Improved agricultural implements	27
	Intensive agricultural district programs	27
	Community development and cooperation	28
	Regional Development	29
III.	POLICY MODELS FOR INDIAN ECONOMY	32
	Mahalanobis Model	32
	Two sector model	32
	Four sector model	37

		Page
	Tintner and Narayanan Model	43
	Notations	43
	Equations	44
	Consumption function	44
	Production function	45
	Labor demand function	45
	Identities	45
	Consumption function	46
	Production function	46
	Labor demand function	47
	Definition equations	48
	Sandee Model	49
	Desai Model	55
	Palvia Model	58
	Narasimham Model	59
IV.	REGIONAL PROGRAMMING MODELS	61
	Regional Input-Output Models	63
	Regional input-output models emphasizing relationship between industries	63
	Regional input-output model emphasizing inter-relation between agriculture and industry	69
	Assumptions of Regional Input-Output Models	70
	Inter-regional Linear Programming Models	75

Page

V. AN INTER-REGIONAL LINEAR PROGRAMMING MODEL FOR AGRICULTURAL DEVELOPMENT PLANNING IN INDIA 87

Objectives of the Study 87

Type of Model 89

Basic Assumptions of the Model 90

The Model 92

Direct problem 100

Resources 101

Intermediate products 101

Final products 101

Transport 102

Dual 110

Production 115

Transport activities 116

Final product 116

Intermediate product 116

Resource 116

Subsidy Prices and Rents to Scarce Resources 133

Accounting Prices 145

Inter-regional Equilibrium Characteristics of the Model 146

Model in the Matrix Notation 151

Primal 158

Dual 159

Production activities 159

		Page
	Transport activities	159
VI.	OPERATIONAL MODELS AND INVESTMENT ALLOCATION	161
	Operational Models	161
	Model A	161
	Model B	167
	Model C	168
	Model D	169
	Model E	173
	Model F	174
	Investment Allocation	178
	Capital-output ratio	179
	Capital-labor ratio	180
	Social marginal productivity criterion	181
	Marginal reinvestment criterion	182
	Marginal growth contribution criterion	182
	Linear programming criterion	182
VII.	RESULTS OF SOME PROGRAMS	197
	Primal	197
	Dual	205
	Programs	207
	Prices	208
	Regional prices model	208
	National prices model	208
	Production coefficients	209

		Page
	Number of programs	210
	Size of programs (467 x 214)	211
	Levels of restrictions for programs	213
	Income and area restrictions	213
	National production restrictions	215
	Results of programs	215
	Overall income for programs	215
	Income from different commodity groups for programs	222
	Production levels for programs	223
	Distribution of areas among different groups of crops	230
	Optimal cropping plans for different programs	238
	Gross rents	239
	Main conclusions from program solutions	239
VIII.	SUMMARY	246
IX.	LITERATURE CITED	254
X.	ACKNOWLEDGEMENTS	267
XI.	APPENDIX	269

I. INTRODUCTION

Regional planning is becoming increasingly recognized as an important dimension of economic planning. In brief, the present study purports to examine how far this important tool of planning is useful for agricultural development planning in India.

A short reference to location theories seems to be an appropriate start for the introduction to regional programming. Von Thünen (1826), the founder of the school of location theory, restricted his analysis primarily to crop farming, given a population cluster within a uniformly fertile plane, isolated from outside influences. Assuming further equal transportation rates, he concluded that the location of different kinds of agricultural production was determined by relation between the price of products in the market and the distance from the market place.

Weber (1928) pursued an essentially evolutionary approach in 1909 to spatial development from the primitive agriculture stage to an advanced degree of industrialization. Instead of equal fertility throughout, he assumed equal cost of fuel and raw materials at all deposits but retained the uneven distribution of such deposits. Hoover (1937) combined the relevant Weberian analysis with the theory of firm and partial equilibrium analysis. He thus brought somewhat closer the two parallel economic approaches, spatial theories and Walrasian general equilibrium analysis.

The first important attempt to integrate general equilibrium analysis and location theory was in 1940, made by Lösch (1954). He developed his theory of market areas based upon empirical evidence and deductive reasoning. Assuming a continuous plane, uniformly and adequately endowed with raw materials, and with uniformly distributed population, full technical knowledge, complete freedom of entry for producers, and equal transportation rates, he demonstrated how a regular hexagonal network of market would evolve.

Among the relatively recent attempts, that of Isard (1956b) and Lefeber (1958b) may be referred to. Isard (1956b) formalized a general location theory. He attempted to generalize the Weberian theory and to synthesize it with market area analysis of Lösch and other related theories. He assumed a continuous transport plane and treated transport input practically as an intermediate product. His emphasis was on developing a general theory of location. The analytical framework of his analysis did not yield relevant Walrasian marginal conditions of optimizing production.

Lefeber (1958b) directed his analysis toward attainment of optimal resource allocation and commodity distribution over space, given prices of final goods in different markets or a welfare relation for spatially separated consumer groups.

The number of discrete location points were incorporated in the analysis rather than a continuous plane of locational possibilities.

Parallel to attempts to fuse Walrasian general equilibrium analysis and location theories, a group of research workers ventured to incorporate transportation in economic analysis. Development of mathematical tools, relevant to economic analysis, namely linear and non-linear programming, encouraged many such research workers to use these instruments in the solution of spatial economic problems. Some of the pioneers among them are Enke (1951), Koopmans (1947), Koopmans and Beckmann (1957), Samuelson (1952), Fox (1953), Fox and Taeuber (1955) and Heady and others (1958, 1961).

The aforesaid developments, especially during the last two to three decades, have given a great fillip to the need of regional analysis. A number of interregional studies have been conducted with various objectives in view. Some of these were directed towards arriving at equilibrium prices of certain commodities in separated markets, some others laid emphasis toward determining optimal allocation of certain resources. To quote some of these studies are of Isard (1951, 1953a and b, 1958), Moses (1955, 1960), Leontief (1953), Chenery and others (1953), Fox (1953), Fox and Taeuber (1955), Heady and others (1958, 1959, 1961), Egbert and Heady (1961a, b and c), Henderson (1956, 1957, 1959), Judge (1956), Stevens (1958) and Snodgrass and French (1958).

These studies and similar other ones have brought out many useful facets of regional analysis in respect to advances in economic theory, in the fields of economic policy and development planning, et cetera. Regional planning is becoming increasingly considered as an important tool of economic development.

India launched its five year plan since 1951-52 with the two main objectives (a) to develop the country at a rapid rate, and (b) to achieve a more favorable distribution of incomes. A number of economic models have been suggested to form the basis for five year plans to achieve these objectives. The purposes of the present study are:

1. to examine how far economic models suggested suit the development of the agricultural sector, the dominating and major single sector of the economy;
2. to review some of the regional studies relevant to the present study, for evaluating the extent to which their analytical frameworks can be useful to agricultural development in India;
3. to develop a general regional programming model appropriate to the objective of planning;
4. to generate some operational models out of the general regional programming model for efficient allocation of

land and some other scarce resources and investment allocation; and

5. to run some programs on the basis of operational models for land use planning in India, within the present limitations of data.

II. INDIAN FIVE YEAR PLANS

India lies between latitudes 8° and 37° north and longitudes 66°21' to 97° east; measuring about 2,000 miles from north to south and 1700 miles from east to west. The total geographical area is about 806 million acres divided into 15 states and 6 union territories. In area, it is the seventh largest country in the world. The total population, according to the 1961 census, is 438 millions, the second biggest population in the world. The country is predominantly rural, about five-sixths (82.16%) of its population residing in villages numbering about six lakhs. The density of population per square mile is 384. The availability per person of cultivatable land is about 0.82 acres as against 0.42 in UK, 0.48 in Germany, 0.17 in Japan, 0.50 in China, 2.68 in USA and 2.59 in USSR. Literate persons comprise 23.7 per cent of the total population. Agriculture is the chief industry, engaging about 71 per cent of the working population, and contributing about one-half to the total national net product.

The Indian National Congress, even as early as 1938 during the freedom struggle, realized the need of planning in the country and a National Planning Committee was constituted. Ever since independence two main objectives (Government of India, 1956, p. 4), to build up by democratic means a rapidly expanding and technologically progressive economy and a social order based on justice and offering equal opportunity to every citizen, have guided the country's planned development.

Early in 1950, following the adoption of the new constitution by the Constituent Assembly, the government of India established the planning commission to assess the country's material, human resources and to formulate a plan for their most effective and balanced utilization. The first five year plan was launched in 1951-52, with a very slender industrial base and limited means. In December 1954, the parliament adopted the 'socialistic pattern of the society' as the objective of social and economic policy. The country is now in the third five year plan. The leading objective of the pattern of development in the five year plans is to provide sound foundations for sustained economic growth, for increasing opportunities for gainful employment, and improving standards and working conditions for the masses.

Land reforms, setting up comprehensive community development programs, revitalization of the cooperative movement, expansion of irrigation and power facilities, strengthening and improving the administrative structure of the economy, and establishing a number of specialized institutions for providing credit to agriculture and industry, for developing small-scale industries and for giving assistance to backward sections of the population were some of the notable features of the first plan. The second plan, initiated in 1956-57, pushed the basic programs started in the first plan further and envisaged a higher level in investment, production and employment. The development of basic and heavy industries was given more emphasis to speed up the rate of development over the next 15 or 20 years. The plan also stated explicitly the role of public sector in the economic development of the country and placed before the nation the goal of the socialistic pattern of the society.

Outlay and Investment

It may be useful to compare the five year plans for some of the key figures.

Table 1. Outlay and investment in five year plans (Rs. crores)[a]

Sector	First plan 1951-56	Second plan 1956-61	Third plan 1961-65
Public sector outlay	1960	4600	7500
Public sector investment	1560	3650	6300
Private sector investment	1800	3100	4100
Total investment	3360	6750	10400

[a]One crore is equal to 10 million.

The national income at 1960-61 prices in 1950-51 was Rs. 10,240 crores, Rs. 12,130 crores in 1955-56, Rs. 14,500 crores in 1960-61 and estimated to be about Rs. 19,000 crores in 1965-66. The rate of total investment thus rose from about 5 per cent of the national income in 1950-51 to 7 per cent in the first plan and to 11.5 per cent in the second plan. It is expected to rise to 14 per cent in the third plan. It involves raising the domestic saving from about 8.5 per cent in 1960-61 to about 11.5 per cent at the end of the third plan.

The financing arrangements of the public sector may be seen in Table 2.

Table 2. Financial resources in the public sector (Rs. crores)

Source	1st plan		2nd plan		3rd plan	
	Actual	%	Actual	%	Actual	%
Outlay of the plan	1960	100	4600	100	7500	100
Internal resources	1772	90	3510	76	5300	70
External assistance	188	10	1090	24	2200	30

Distribution of the Outlay in the Public Sector

The distributions of outlay as indicated in Table 3 reflect the changes in emphasis in the plans. The share of agriculture and irrigation decreased from 31 per cent in the first plan to 20 per cent in the second plan; it has again gone up to 23 per cent in the third plan. In the second plan greater emphasis was placed on industrial development, the share for which rose from 4 per cent to 20 per cent. This emphasis seems to have been maintained in the third plan too.

Transport and communications were given higher priority in the first two plans than in the third one. Social services and miscellaneous items have shown declines in their proportions over time.

Selected Indicators of Growth

A general view of the growth of the economy over the last decade may be obtained from the values of the selected indicators in Table 4; the corresponding targets for these values for 1965-66 are also included therein.

The increase in national income during the first plan was 18 per cent as against the target of 12 per cent. During the second plan, on the other hand, the increase in national income was 20 per cent as against a target of 25 per cent.

Table 3. Distribution of outlay (Rs. crores)

Item	First plan 1951-56		Second plan 1956-61		Third plan 1961-65	
	Value	%	Value	%	Value	%
Agriculture and community development	291	15	530	11	1068	14
Major and median irrigation	310	16	420	9	650	9
Power	260	13	445	10	1021	13
Village and small industries	43	2	175	4	264	4
Industries and minerals	74	4	900	20	1520	20
Transport and communications	523	27	1300	28	1486	20
Social service and miscellaneous	459	23	830	18	1300	17
Inventories	-	-	-	-	200	3
Total	1960	100	4600	100	7500	100

Table 4. Selected indicators of growth

Item	Unit	1950-51	1955-56	1960-61
National income at 1960-61 prices	Rs. crores	10,240	12,130	14,500
Population	Millions	361	397	438
Per capita income at 1960-61 prices	Rs.	284	306	330
Index of agriculture production	1949-1950=100	96	117	135
Food grains production	Million tons	52.2	65.8	76.0
Nitrogenous fertilizers	000 tons N	55	105	230
Area irrigated	Million acres	51.5	56.2	70.0
Cooperative movement advance to farmers	Rs. crores	22.9	49.6	200.0
Index of industrial production	1950-1951=100	100	139	194
Consumption levels: Food	Calories p.c. per day	1,800	1,950	2,100
Cloth	Yards p.c. per annum	9.2	15.5	15.5

Table 4. (Continued)

Item	P.c. increase in 1960-61 over 1950-51	Targets for 1965-66	P.c. increase in 1965-66 over 1960-61
National income at 1960-61 prices	42	19,000	30
Population	21		
Per capita income at 1960-61 prices	16	385	17
Index of agriculture production	41	176	30
Food grains production	46	100	32
Nitrogenous fertilizers	318	1,000	335
Area irrigated	36	90	29
Cooperative movement advance to farmers	773	530	165
Index of industrial production	94	329	70
Consumption levels: Food	17	2,300	10
Cloth	68	17.2	11

The targets of agricultural production were mainly reached, as originally planned in the second plan, but there were some short falls as the achievements were compared with the revised targets. There were significant short falls in the attainment of targets for steel, fertilizers, paper and cement plant machinery, et cetera.

There was a back-log of unemployed persons of about 5.3 million at the beginning of the second plan. The additional employment opportunities created in the course of the second plan amounted to 8 million (as against 10 million envisaged), of which about 6.5 million were outside agriculture. About 11.7 million were new entrants in the labor force during this period. The back-log of unemployed persons at the beginning of the third plan thus stands at 9.0 million. On the basis of population trends at present, it is estimated that the addition to the labor force will be of the order of about 17 million during the third plan. It is estimated that the programs in the plan may provide additional non-agricultural employment of the order of 10.5 million and additional employment in agriculture of about 3.5 million. The total employment generated comes to 14 million only, not sufficient to absorb the new entrants to the labor force during the period, not to speak of the 9 million back-log.

Agriculture

It may be useful for the present study to look into more details in some of the facts about agriculture.

The trend of agricultural production since 1949-50 and the estimated levels for 1965-66 are as given below.

Table 5. Index of agricultural production (1949-50 = 100)

Group	1950-1951	1955-1956	1960-1961	1965-66 (estimated)	% increase in 1965-66 over 1960-61
All crops	96	117	135 (139)[a]	176	30
Food crops	91	115	132	171	30
Other crops	106	120	142	186	31

[a]Revised.

The cumulative rate of growth up to 1960-61 was about 3.5 per cent per annum. The present plan proposes stepping the rate to about 6 per cent.

The increase in production of major crops is indicated in Table 6.

The level of food grains for 1960-61, shown as 76 million tons, has reached about 79 million tons when the revised estimates of crop production are used. The second

Table 6. Production of major crops

Item	Units	1950-1951	1955-1956	1960-1961	Original targets for 2nd plan	Revised targets for 2nd plan	1965-1966	% increase in 1965-1966 over 1960-1961
Food grains (cereals and pulses)	Million tons	52.2	65.8	76.0 (79.3)[a]	75.0	80.5	100.0	32
Oil seeds	Million tons	5.1	5.6	7.1 (6.6)	7.0	7.6	9.8	38
Sugar cane (gur)	Million tons	5.6	6.0	8.0 (8.4)	7.1	7.8	10.0	25
Cotton	Million bales	2.9	4.0	5.1 (5.4)	5.5	6.5	7.0	37
Jute	Million bales	3.3	4.2	4.0 (4.0)	5.0	5.5	6.2	55

[a]Figures in parentheses are revised estimates.

plan targets for sugar cane have been exceeded. Cotton and jute levels fall below, even the original targets. Oil seeds have surpassed the original target but have remained below the revised one.

The land utilization pattern corresponding to the afore-mentioned production figures is as below.

Table 7. Land utilization (million acres)

	1955-56	1960-61	1965-66
Total reporting area	720.0	721.0	721.0
Forests	125.6	131.0	132.0
Land under miscellaneous tree crops and groves	13.9	14.0	15.0
Permanent pastures and other grazing lands	28.4	32.0	32.0
Cultivatable waste	54.8	47.0	40.0
Barren and uncultivated land put to non-agricultural use	118.7	114.0	114.0
Fallow lands other than	30.9	28.0	26.0
Current fallows	29.5	28.0	25.5
Net area sown	318.2	327.0	335.0
Area sown more than once	44.4	51.5	67.0
Gross area sown	362.6	378.5	402.0

The gross cropped area is proposed to be stepped up through extension of area under cultivation by reclaiming waste lands and through intensive cultivation of cropped areas. The cultivable area per person is about 0.82 acres. The net area sown per person which was 0.81 acres in 1951 was reduced to 0.75 acres in 1960-61 and is expected to be reduced further to 0.68 acres in 1965-66.

The public outlay in agricultural production for the second and third plans is given below.

Table 8. Outlay on agricultural production (Rs. crores)

Item	Second plan	Third plan
Agricultural production	98.10	226.07
Minor irrigation	94.94	176.76
Soil conservation	17.61	72.73
Cooperation	33.83	80.10
Community development agricultural programs	50.00	126.00
Major and medium irrigation	372.17	599.34
Total	666.65	1281.00

The total outlay for agriculture in the third plan is nearly double that of the second plan.

Instruments for Increasing Agricultural Production

The instruments used and/or proposed to be used for increasing agricultural production can be classified as follows:

1. Land reform
2. Technical
3. Community development and cooperation
4. Others.

Land reform

> Land reform programs, which were given a place of special significance both in the first and in the second plan, have two specific objectives. The first one is to remove such impediments to increase agricultural production as arise from the agrarian structure inherited from the past. This should help to create conditions for evolving as speedily as possible an agricultural economy with high levels of efficiency and productivity. The second object, which is closely related to the first, is to eliminate all elements of exploitation and social injustice within the agrarian system, to provide security for the tiller of soil and assure equality of status and opportunity to all sections of the rural population. (Government of India, 1961, p. 220)

The abolition of intermediary tenures like Zamindaris, Jagirs and Inams, which covered more than 40 percent of the area, has almost been completed. It has brought more than 20 million tenants into direct relationship with the state.

The rent paid by tenants-at-will, share croppers, et cetera over a greater part of the country was one-half of the produce or more. Almost all states have enacted legislation for regulating rents, over the past few years. The rent now varies from 1/3 to 1/6 of the produce in different states.

Legislation for security of tenure has been enacted in eleven states and in all union territories and is expected to be enacted soon in the remaining four states. It will not allow ejectments except under provisions of law; the land may be resumed by an owner, if at all, for personal cultivation only; and in the event of resumption, the tenant is assured of a prescribed minimum area.

Ceilings on agricultural holdings legislation have been passed in a number of states, and other states are following. Though it was realized that with the pattern of distribution of agricultural holdings which emerged from land reforms, the land in excess of any given level of ceiling was not likely to make available any large areas for redistribution. It was considered that such a reduction in disparity and checking the accumulation of land in a few hands was a necessary condition for building up a progressive cooperative rural economy.

Consolidation of holdings has made a quite significant progress. By the end of 1959-60, about 23 million acres had been consolidated.

The task ahead in land reform is to create awareness among the people, in general, and to get them to avail themselves of the benefits accrueing to them by the above-mentioned legislation. The implementation of these programs of land reforms will make India mostly a land of peasant proprietors.

Technical

The major technical programs for increasing agricultural production are (a) irrigation, (b) soil conservation, dry farming and land reclamation, (c) supply of fertilizers and manures, (d) seed multiplication and distribution, (e) plant protection, (f) better plows and improved implements, and (g) adoption of scientific agricultural practices.

The outlay under broad headings has already been mentioned. The achievements in the second plan and targets for the third are given in Table 9.

Irrigation Irrigation is one of the most important basic factors for agricultural progress in India, as under natural conditions in most parts of the country, cultivation of land tends to remain a single-crop, precarious occupation. About 17 per cent of the cultivated area is irrigated, another 16 per cent, assured of rainfall, could be added, while the remaining 2/3 must depend on the vagaries of rainfall.

It has been estimated that out of the total usable annual flow (450 million acre feet of water), only 27 per cent is currently used, and only 36 per cent is anticipated to be used by 1965-66. The actual utilization of the under-

Table 9. Agricultural programs

Item	Unit	2nd plan achievements	3rd plan targets
Irrigation			
Major & medium irrigation (gross)	Million acres	6.9	12.8
Minor irrigation (gross)	"	9.0	12.8
Soil conservation, land reclamation, etc.			
Soil conservation on agricultural lands	Million acres	2.0	11.0
Dry farming	"	-	22.0
Land reclamation	"	1.2	3.6
Additional area under improved seeds (food grains)	Million acres	55	148.0
Consumption of chemical fertilizers			
Nitrogen (N)	Thousand tons	230	1000
Phosphatic (P_2O_5)	"	70	400
Potassic (K_2O)	"	25	200
Organic and green manuring			
Urban compost	Million tons	3	5
Rural compost	"	83	150
Green manuring	"	11.8	41
Plant protection	Million acres	16	50

ground water is less than 20 per cent of annual enrichment, the water which is added annually to the underground water after deducting the amount estimated to be used as soil moisture in top layers. The irrigation potential of major and medium irrigation projects is estimated at 100 million acres and that for minor projects at 75 million acres. This potential of 175 million acres, if realized during the next 20 - 25 years, can raise the ratio of irrigated to cultivated area to 50 per cent (of 350 million acres). This would use 60 per cent of the total annual water supply from both surface and underground resources, and it will leave an adequate supply for other resources.

The progress of irrigation and targets for 1965-66 are as follows.

Table 10. Area irrigated (million acres)

	1950-1951	1955-1956	1960-1961	1965-1966
Major and medium irrigation	22.0	24.9	31.0	42.5
Minor irrigation	29.5	31.3	39.0	47.5
Total	51.5	56.2	70.0	90.0

Worth noting is the fact that out of the total irrigation potential, 6.5 million acres up to 1955-56 in the second plan, only 48 per cent (3.1 million acres) was utilized. The corresponding estimated figures for 1960-61 are: potential, 13.2 million acres; area irrigated, 10.0 million acres; and percentage of potential utilized, 76 per cent. The lag in the potential and actual utilization has been described as due to (a) lack of timely excavation of field channels and (b) failure to demonstrate to the cultivators, in advance, improved techniques of agriculture and the most suitable cropping pattern to be adopted when irrigation facilities become available.

The total irrigation potential remaining idle at the end of the second plan is 3.2 million acres. The additional potential, about 16.2 million acres, will be created in the third plan. The total utilization is expected to be 12.8 million acres gross by the end of the third plan.

<u>Soil conservation, dry farming and land reclamation</u> It is estimated that about 200 million acres of land, almost 25% of the total land, is suffering from soil erosion. It is feared that it will not be possible to maintain the present productivity of dry lands, much less to increase it, unless conservation measures are adopted. Irrigated areas in some parts suffer from water logging and consequent salinity and alkalinity.

A sum of Rs. 1.6 crores was spent in the first plan and Rs. 18 crores in the second plan for soil conservation. The proposed expenditures in the third plan are Rs. 72 crores. The measures included for soil conservation are contour bunding and dry farming techniques, river valley projects for afforestation of catchment areas, reclamation of alkaline and 'usar' lands, et cetera. The area under different categories is given in Table 9.

Fertilizers and manures The demands for fertilizers surpassed the supply by a substantial margin during the second plan. The provisional schedule of supply for the third plan is as follows.

Table 11. Supply of fertilizer (thousand tons)

Year	Nitrogenous fertilizers N	Phosphatic fertilizers P_2O_5	Potassic fertilizers K_2O
1960-61	230	70	25
1961-62	400	100	82
1962-63	525	150	100
1963-64	650	225	130
1964-65	800	300	160
1965-66	1,000	400	200

A central fertilizer marketing corporation is proposed to set up to deal effectively with problems arising out of increased distribution of fertilizers and their storage, sales promotion, et cetera.

The use of organic and green manuring has been proposed to be stepped up substantially (Table 9). Soil testing arrangements will be enhanced.

Seed multiplication and distribution The area under improved seeds among food crops was estimated at 55 million acres (20% of the area under food crops). It is estimated to be stepped up to 148 million acres (50% of the area under food crops) by the end of the third plan (1965-66). The seed farms established in development blocks will produce the foundation seed of improved varieties which will be multiplied further by registered growers.

In all, about 4000 seed farms are reported to have been set up by 1960-61 and about 800 more will be set up each year in the third plan. Special attention is being given to extension of the area under hybrid corn. By 1965-66, about 25 per cent of the total maize area is proposed to be covered by hybrid corn.

Plant protection Plant protection measures did not get due importance during the last decade planning. The precise estimated loss caused to agricultural production due to lack of plant protection measures is not known, but general agreement is that it is serious and substantial. The area to be covered by such measures is proposed to be increased from 16 million acres in 1960-61 to 50 million acres in 1965-66.

Improved agricultural implements It has been an admitted fact that a serious gap in the agricultural programs undertaken during the first and second plans has been in the field of improved agricultural implements. The outlay provision in the third plan is Rs. 8 crores for this purpose. A comprehensive scheme to improve matters has been suggested in this plan.

Intensive agricultural district programs

The agricultural production team sponsored by the Ford Foundation (1959) observed that there was no inherent soil, climate or other physical reason for the present low yields. The team, therefore, suggested that those selected crops and those selected areas in each state should be chosen which have the greatest increase potentialities. In pursuance of the proposal, an intensive agricultural district program has been initiated within each state. The essential elements for increasing production will be supplied to farmers in an integrated form. This experiment may yield useful results which could be adopted over the entire country.

Community development and cooperation

The community development now serves 3,100 development blocks comprising about 370,000 villages. By October, 1963, the entire country is estimated to be covered by these blocks.

The community development program covers three facets: extension function, introduction of democratic institutions, and preparation and implementation of area plans. The last facet envisages making the block as a unit of planning and development. For the third plan, it has been stated that local plans should be worked out as a means for more effective implementation of the state plan. Until now, the main emphasis among the three facets has been on extension. Legislation for introduction of Panchyali Raj has been enacted in about seven states.

Cooperation has been given a place of pride in planning. It has been stated in the third five year plan (Government of India, 1961, p. 200) that

> Within the rural economy in particular, cooperation is the primary means for raising the level of productivity, extending improvements in technology and expanding employment so as to secure basic necessities for every member of the community.

The outlay in the third plan for development of cooperation is Rs. 80 crores as against Rs. 34 crores in the second plan.

Over the two plan periods, the number of primary agricultural credit societies has risen from about 105,000 to about 210,000 and their membership from 4.4 to about 17.0 millions. The number of such societies is proposed to be increased to 230,000 so as to serve all the villages in the country. Their membership may come to 60 million covering about 60% of the agricultural population.

Development of cooperative marketing, cooperative processing, cooperative farming, et cetera has been given due consideration. There are already 1869 primary marketing societies, and with the addition of 600 more in the third plan, there will be a marketing society at or near each of the 2,500 'madis' in the country. Out of these 2,500 'mandis', 725 are regulated ones. The remaining ones will be brought under the scheme of legislation in the third plan.

Regional Development

The second five year plan explicitly adopted a number of regional development goals to be achieved through economic development. The major one is

> In any comprehensive plan of development, it is axiomatic that the special needs of the less developed areas should receive due attention. The pattern of development must be so devised as to lead to balanced regional development. (Government of India, 1956, p. 28)

The balanced regional development theme was strongly endorsed in the official industrial resolution, 1956, and it was visualized that facilities such as power, water supply and transport should be made available in areas which are at present lagging behind industrially or where there is a greater need for providing opportunities of employment, so that suitable industries should be developed there. The general approach set out in the second plan was pursued through various programs, priorities given to agricultural development projects, provision of power, expansion schemes for village and small scale industries, location of public enterprises, et cetera.

The plan also envisaged an attempt to promote greater mobility of labor between different parts of the country.

The 'regional balance development' so far had mainly emphasized the development of regions which had lagged behind. To some extent regional development criterion seems to have been taken in allocation of funds in different states and among different projects. However, there does not seem to be sufficient clarity up to this stage as to what is included in regional development and what is out of it.

The third plan (Government of India, 1961, p. 142) further clarifies the concept.

> Balanced development of different parts of the country, extension of benefits of economic progress to the less developed regions and wide spread of diffusion of industry are among major aims of planned development.

But in view of the limited resources, the advantage of concentration at those points within the economy at which the returns are likely to be favorable are recognized in the third plan (Government of India, 1961, p. 142).

> Once a minimum in terms of national income and growth in different sectors is reached, without effecting the progress of the economy as a whole, it becomes possible to provide in many directions for a larger scale of development in the less developed regions.

The plan further clearly suggests eliminating the excessive emphasis on problems of particular regions and attempts to plan for their development without retarding their share of the requirements of the national economy. This explanation of the regional development shifts the emphasis from developing the regions with low incomes to the optimal utilization of the regional and national resources for meeting the plan's objectives.

III. POLICY MODELS FOR INDIAN ECONOMY

It is proposed to examine some of the policy models suggested for Indian planning. The foremost among these is the Mahalanobis Model. It was one of the important working papers used in preparing the second five year plan.

Mahalanobis Model

In September 1954 a question was posed by the finance minister in connection with the basic approach to the formulation of the second five year plan (Mahalanobis, 1955):

> Is it possible to prepare a plan which would enable unemployment being liquidated in 10 years and which would also provide for a satisfactory increase in national income at the same time?

Professor Mahalanobis (1953) had already developed a two sector model which he further extended to a four sector model, to take into account the above mentioned objectives.

Two sector model

The two sector model of Mahalanobis has a similarity to the Harrod-Domar Model (1946, 1957) in assuming output-capital ratio as constant.

In the Harrod-Domar Model the economy is not subdivided.

$$\Delta Y_t = BI_t$$

$$S_t = sY_t$$

$$I_t = sY_t$$

(3.1)

$$\therefore \Delta Y_t/B = sY_t$$

$$\Delta Y_t/Y_t = sB$$

$$Y_t = Yo\ (1 + sB)^t$$

where Y_t is the national income; S_t is savings; s_t, saving rate; I_t, investment, K, capital and B, output-capital ratio.

In this model $\Delta Y_t/Y_t = \Delta I_t/I_t = \Delta K/K = sB$. This is called an equilibrium rate of growth. s and B are assumed to be constant. The policy implications of the above model can be posed in a fashion that if the desired rate of growth is r, then s should be equal to γ/B, whether s could be manipulated or B should be improved to γ/s. The rate of growth of per capita income $\overline{\gamma} = sB - p$. p is the rate of increase of population.

The Mahalanobis two sector model (1955) similarly assumes the output-capital ratio to be constant. The economy is divided into two sectors, the investment goods sector (k) and the consumers' goods sector (c). Sectors are assumed to be vertically integrated, and the problem of intermediary goods is solved by aggregating sectors producing raw materials for consumption-goods with the consumption-goods sector and similarly for the investment-goods sector. No international trade is assumed.

I_t has been divided into two parts: $d_k I_t$ and $d_c I_t$, where d_k indicates the proportion going to sector k and d_c to sector c.

$$I_t - I_{t-1} = B_k d_k I_{t-1}$$

$$C_t - C_{t-1} = B_c d_c I_{t-1}$$

From the above two equations, it follows

$$I_t = I_o (1 + d_k B_k)^t$$

$$I_t - I_o = I_o \{(1 + d_k B_k)^t - 1\}$$

$$C_t - C_o = B_c d_c I_o \frac{(1 + d_k B_k)^t}{d_k B_k} - 1$$

Adding the above two we get

$$(3.2) \quad Y_t = Y_o \left[1 + \alpha_o\left(\frac{B_c d_c + B_k d_k}{B_k d_k}\right)\{1 + B_k d_k)^t - 1\}\right]$$

α_o, being the initial rate of saving, B_k and B_c being fixed, the variables which could be manipulated seem to be d_k and d_c. As the relation $d_k + d_c = 1$, then if either one is chosen, the other is automatically fixed. The policy instrument being one only and only one target could be considered. The target chosen by the author is the rate of growth of national income. The marginal rate saving or investment changes from initial period α_o to $\frac{d_k B_k}{d_k B_k + d_c B_c}$ where it remains constant as in the Domar model.

B_k is generally less than B_c. In that case, it may be seen that a higher value of d_k gives a lower value of Y_t, for small values of t, but higher values of Y_t for more advanced time. The reason is that higher value of d_k increases the magnitude of $(1 + d_k B_k)^t$ while it lowers the value of the ratio $\frac{B_c d_c + B_k d_k}{B_k d_k}$. The reduction of Y_t in the beginning due to decrease in above ratio may be larger than the increase in Y_t brought by the other expression. But as the time passes $(1 + d_k B_k)^t$ will tend to dominate, so that higher value of d_k would mean a higher value of growth in future time.

The author adopted $d_k = \frac{1}{3}$ on the basis of the pattern of growth emerging from certain values of B_k and B_c which were considered to be reasonable estimates of these parameters under Indian conditions (Mahalanobis, 1955, p. 38).

> . . . The growth of the economy is slower for larger values of d_k up to a critical period. Once the critical period is passed the higher values of d_k or B_k (or of both), the quicker is the growth of the income over a long period of 20 or 30 years.

Haldane (1955) derived the optimum value of d_k for maximizing rate of growth of national income over the specified planning horizon.

$$(3.3) \quad t = 2(B_k^{-1} - B_c^{-1})(1 + \frac{1}{3} Z + \frac{5}{36} Z^2 + \frac{17}{270} Z^3 + \frac{193}{6480} Z^4 + \ldots)$$

where $Z = 2(B_c - B_k)\, d_k/B_c$.

The following results are obtained.

d_k	0	0.1	0.2	0.3
t	13.3	14.0	14.5	15.3

Four sector model

Professor Mahalanobis (1955) developed a four sector model for the second five year plan, to take into account two additional targets, i.e. increase in national income (Y) and employment (N). After the first stage allocation between two sectors k and c, the sector c was further subdivided into three sectors as

c_1 = basic investment goods,

c_2 = household industries (including agriculture),

and c_3 = services.

The B's corresponding to c_1, c_2, and c_3 were designated as B_1, B_2, and B_3, and the net investment required per person (capital-labor ratios) as θ_1, θ_2 and θ_3 respectively.

If ΔN is the total number of additional persons engaged over the plan period, ΔY is the increase in income, and A is the total investment over the whole plan period, then we have

$$A = n_k\theta_k + n_1\theta_1 + n_2\theta_2 + n_3\theta_3$$

$$= d_kA + n_1\theta_1 + n_2\theta_2 + n_3\theta_3$$

$$\Delta N = n_k + n_1 + n_2 + n_3$$

$$\Delta Y = B_k\theta_k n_k + B_1\theta_1 n_1 + B_2\theta_2 n_2 + B_3\theta_3 n_3$$

$$\equiv Y_o(1 + \eta)^5 - 1$$

η has been taken as 5 per cent, the allocation to sector k has already been decided from long-term considerations, and the allocation to the remaining three sectors is based on the solution of the above simultaneous equations.

At this stage the two targets are ΔY and ΔN and instruments d_1, d_2 and d_3. The two, out of three, d's are free. It makes two targets and two instruments.

Sector two has been further subdivided into two: agriculture (a) and small and household enterprise (h).

Now the problem is formulated as

$$n_a + n_h = n_2$$

$$(3.5) \qquad n_a\theta_a + n_h\theta_h = \theta_2 n_2$$

$$B_a n_a\theta_a + B_h n_h\theta_h = B_2 n_2\theta_2$$

The values of B_h, θ_a and θ_h are known. The solution of the above equation gives us $B_a = 1.10$.

The allocation shown by the model was not exactly pursued in the second five year plan, but broadly it tallies with it. The importance of the model can be seen from the fact that it is the 'statistical basis' of the draft plan frame for the second plan prepared by Mahalanobis.

The utility of the model rests on the accuracy of BS and θS ratios. Their values are given in Table 12.

Table 12. Output-capital (B) and capital-labor coefficients (θ)

Sector	Parameters	
	B	θ (Rs.)
K	$B_k = 0.20$	$\theta_k = 20{,}000$
C_1	$B_1 = 0.35$	$\theta_1 = 8{,}750$
C_2	$B_2 = 1.25$	$\theta_2 = 2{,}500$
C_3	$B_3 = 0.45$	$\theta_3 = 3{,}750$

The values of Bs as used in the model in most cases seem to be rough approximations. It has been stated that very little direct data are available for estimation of B for agriculture. National income data on income and investment yield output-capital ratio of about 1.5 for agriculture and household enterprise combined (1951-52). The author adjusts this figure to 1.25 as a reasonable value. Similarly, for estimations of other Bs, approximations have played a significant role. Same is the case in deriving θs (labor-capital ratios).

The model though considers four sectors is still quite aggregative; the Bs are used in a manner as if the investment is a single homogeneous fund. Actually, the investment goods industry is likely to change its composition over time.

The θs (labor-capital ratios) are assumed to be independent of Bs (output-capital ratio). This has been criticized by some research workers, such as Professor Shigeto Tsuru (1957).

The simultaneous equations system, for allocation of investment within Sector 2 (between agriculture and household), is overdeterminate if θs and Bs are known. But here the author solves for B_a and the allocation of investment. Komiya (1959), criticizing this method, has pointed out that parameters, capital-output ratio and labor-output ratio, in the agriculture sub-sector, are made dependent on the availability of investment funds, targets of national income and labor absorption. Actually, these parameters are determined by technological conditions.

Komiya (1959) has further shown that the allocation among the three consumption sectors, after 1/3 of the investment has been allotted to investment goods sector, as given by Mahalanobis, does not maximize ΔY under the constraints of additional employment to be created and the investment given. His solution indicates, while all labor, 10.1 million (0.9 million absorbed in investment goods sector) will be absorbed, a considerable amount of investment funds will not be used and all productive effort should be concentrated in c_2 (household industries including agriculture) and the resultant increase in Y will be greater. The solution shows labor scarcity and capital abundance, which is contrary to the reality. Some doubts are raised on the utility of the model on account of this solution.

The model takes demand for different goods produced as granted and assumes constant relative prices. It, thus, ignores price and demand considerations completely. In economic planning, the problem of finding optimal resource allocation is very closely connected with the problem of giving right prices to factors of production. The foreign trade, too, is not taken into account explicitly, though in the four sector model, it is assumed that a large amount of capital goods will have to be imported. This may lead to a problem of balance of payment. Actually, the country had to face this problem in the beginning of the second five year plan.

The Mahalanobis model raised the interests of many research workers in different countries and attempts were made to adjust and refine it by making it into a multi-sector one, including in it the Stochastic element, maximizing of rate of absorption of the employment at the first stage of optimization, instead of rate of growth, while finding out d_k and d_c, et cetera. Another interesting interpretation in respect to demand function derived from the model is:

$$(3.6) \quad \frac{Y_t - Y_o}{c_t - c_o} = \frac{B_c d_c + B_k d_k}{B_c d_c} = 1 + \frac{B_k d_k}{B_c(1 - d_k)} = \mu$$

B_k, B_c, and d_k are given so μ is a constant.

From the above relation we can derive the equilibrium function:

$$(3.7) \quad C = \frac{1}{\mu} Y + \frac{\mu c_o - y_o}{\mu}$$

For equilibrium the consumption function should be as above. The actual validity of the above consumption function could be checked by getting an independent consumption function from income-consumption data. If there is a significant difference between the two, a suitable change in the value of d_k or the imposition of price controls on consumption would be necessary. The choice would depend upon the objectives of the economic policy.

Tintner and Narayanan Model

The model specified by Tintner and Narayanan (1961) divides the economy into broad two sectors, namely households and enterprises, represented by two behavioral equations, the consumption function and the labor demand function, respectively.

The technical relation is the only one indicated by the production function. The other equations are identities.

<u>Notations</u>

C_t = private consumption expenditure at current prices in Rs. abja (billion) in period t;

y_t = gross national income at current prices in Rs. abja in period t;

p_t = price level in the year t over the base year expressed as a proportion;

N_t = population in the year t expressed in billion;

Y'_t = income of private persons in the year t expressed in Rs. abja;

Y''_t = private disposable income in the year t expressed in Rs. abja;

x_t = gross physical product in the year t measured in Rs. abja;

D_t = average number of persons 'employed' per day in the year t in billion;

k_t = stock of fixed capital in real terms at the beginning of the year t, expressed in Rs. crores;

w_t = average money wage rate in the year t in Rs. per person per annum;

G_t = government consumption expenditure at current prices in the year t in Rs. abja;

I_t = gross fixed investment at current prices in Rs. abja in the period t;

A_t = net charges in stocks at current prices in Rs. abja in the period t;

L_t = balance of foreign trade at current prices in Rs. abja in the period t;

T_{it} = total indirect taxes in the year t in Rs. abja;

S_t = government subsidies in Rs. abja in the period t;

T_{pt} = (national debt interest + transfer payments + net private donations from abroad) in Rs. abja in the period t;

D'_t = depreciation of capital;

U_{3t} = shock term in Equation 1 assumed to be distributed as $N(0, \sigma_3)$;

U_{4t} = shock term in Equation 2 assumed to be distributed in log normal form: log U_{4t}; and $N(0, \sigma_4)$

U_{5t} = shock term in Equation 3 assumed to be distributed log normally: log U_{5t} $N(0, \sigma_4)$

Equations

Consumption function

$$\frac{C_t}{P_t\ N_t} = \underset{(20.567)}{72.367} + \underset{(0.079)}{0.674}\ \frac{Y''_t}{P_t \cdot N_t} + U_{3t} \qquad (1)$$

Production function

$$X_t = 10^{-18} \times 9.715 \times D_t^{0.201} \times k_t^{3.874} \times U_{4t} \qquad (2)$$

Labor demand function

$$\frac{D_t\ W_t}{X_t\ P_t} = 0.201\ U_{5t} \qquad (3)$$

(3.8) Identities

$$Y_t = X_t\ P_t \qquad (4)$$

$$Y_t = C_t + F_t \qquad (5)$$

$$y_t = Y''_t + E_t \qquad (6)$$

$$F_t = G_t + I_t + A_t + L_t - T_{it} + S_t \qquad (7)$$

$$E_t = Y_{at} + T_{dt} - T_{pt} + D'_t \qquad (8)$$

Standard errors are given within parentheses.

<u>Consumption function</u> The exploratory variable is the per capita disposable income. The dependent variable, the private consumption per capita in real terms, is assumed to be related linearly to per capita real disposable income.

<u>Production function</u> The scantiness of the data though is a serious limitation of all the relations in the model. But the authors (1961) particularly remarked in this case

> For one thing in no country is available data on K_t....so what has been available to econometricians is only some indirect method of estimation.

The Cobb Douglas form of production function has been employed.

$$K_t = K_{t-1} + I'_{t-1}$$

$$K_t = K_T - \sum_{i=t+1}^{T} I'_{t-1}$$

$$K_t = K_T - (\Delta K)_t$$

where $(\Delta k)_t = \sum_{L=t+1}^{T} I'_{t-1}$

I'_t = net fixed investment

$t = 1, 2, \ldots, T$

Substituting for K_t in the production function

$$X_t = A\, D_t^{n_1} \left[K_T - (\Delta K)_t \right]^{n_2} U_{4t}$$

$$\text{Log } X_t = \left[\text{Log } A + n_2 \log K_T \right] + n_1 \text{ Log } D_t$$

$$-n_2 \frac{(\Delta K)_t}{KT} - n_2 \frac{(\Delta K)_t^2}{2K^2T} + \log U_{4t}$$

All parameters are identified now, and it gives us the estimate of stock of fixed capital too.

Actually, the production function is fitted by putting $n_1 = 0$. Afterwards the elasticity of labor as estimated from labor demand function (0.201) was plugged into the production function.

Labor demand function The labor demand function has been derived under the conditions of perfect completion both in producers and factor markets.

$$\frac{dx_t}{dD_t} = \frac{W_t}{P_t} U'_{5t}$$

i.e. $$\frac{X_t}{D_t} = \frac{W_t}{P_t} \cdot U'_{5t}$$

$$\frac{D_t \cdot W_t}{X_t \cdot P_t} = n_1 \cdot U_{5t} \quad ; \quad \frac{1}{U'_{5t}} = U_{5t}$$

<u>Definition equations</u> Equations 4 to 8 are definition equations in the model.

The endogenous variables are: C_t, Y''_t, X_t, Y_t, P_t, and D_t; and the exogenous ones are: W_t, N_t, K_t, F_t and E_t. The model equations are mostly fitted by the least square method and then the reduced forms equations, expressing endogenous by the exogenous ones, were derived.

In the final model, the disturbance terms in the structural equations were set equal to mean value zero (unity in Equations 2 and 3) and the deterministic model was obtained. The reduced forms expressing each endogenous in terms of exogenous (W_t, N_t, K_t, F_t and E_t) were obtained and some policy implications arising out of the model were shown, with respect to the effect of wage rates, investment, population increases, foreign assistance, taxes, transfer payments to the public and such other questions.

The authors are quite aware of the limitations of data. The information for the period 1948-49 to 1957-58 is mostly used. The authors, too, pointed out the bias in parameters due to the method of estimation. Apart from this, the production function, which is one of the very important equations in the model, is estimated very roughly. K_t is estimated indirectly and the elasticity of labor has been taken from the labor demand function, based on perfect competition assumption. The elasticity for capital turns out to be as high as 3.874 and for labor as low as 0.201.

The production function is for the economy as a whole, which throws further doubt on its utility, since even in the two broad sectors of the economy, agriculture and non-agriculture sectors, the parameters of the production functions are likely to be very different.

The model, in view of the above and many other weaknesses, could at most be employed for demonstrative purposes.

Sandee Model

Sandee (1960) built up a comparatively long-run, 1960-70, model titled 'A Demonstration Planning Model for India'. He combines in the model the input-output technique with linear programming, in order to maximize consumption for 1970 under certain constraints of investment, consumption, and foreign trade. He then comes out with the output levels for 1970, investment pattern, and the likely input-output table.

The author derives the input-output table for 1960, assumed state of affairs, by means of projections available for the second five year plan, from the input-output table for 1953-54. The input-output ratios for 1953-54 thus forms a basis, with the only marked exception of electricity. In this case, the input coefficient has been raised by 4 times. The fertilizer column was not obtained from the 1953-54 table, but from project reports for new fertilizer plants. Many of the capital-output ratios used in the model were based on an analysis of balance sheets of companies and a special tabulation of the sample survey of manufacturing industries, both bertaining to 1953. No such capital-output ratio has been specified for agriculture. In addition, a constant stock-output ratio is supplemented by the further assumption that stock in 1960 and 1970 will be at normal level.

The selection of sectors is limited by the availability of data for 1953-54, which distinguished 36 industries. Some sectors are included separately on account of the importance given to them in official planning. The following sectors were finally decided upon;

21. agriculture (including plantations, fishing, and small scale food industries),
22. large scale food manufacturing,
23. steel industry,
24. electrical power industry (both thermal and hydro),
25. coal mining,
26. fertilizer industry (nitrogenous fertilizers only),

27. transport,

28. heavy engineering,

29. other equipment industry,

30. other large scale industries (including other mining),

31. construction (including the cement and small scale building material industries),

32. small scale industries,

33. housing.

The first twelve equations of the model (for 1960) are of the Leontief type. They show how the output of each sector is divided over inputs and final bills of goods. No such equation is set up for housing (33) as $x_{33} = c_{33}$.

The equation (13),

$$(3.9) \quad x_{21} = 4.0\, x_{26.21} + (2.4\, i_{31.21} + 514) + (3.7\, i_{34} + 520)\ ,$$

explains the rise in agricultural output due to increase in fertilizer use $x_{26.21}$, irrigation projects executed $i_{31.21}$ and agricultural extension i_{34}. The coefficients for fertilizer and irrigation have been derived on the assumption made in the second five year plan that one ton of ammonium sulphate would increase food grains output by 2 tons (at Rs. 415 per ton) and that one acre of irrigation would give rise to 0.2 tons of food grains. As the effects of fertilizer and irrigation extend further than food grains, their effects have been raised by 50 per cent (arbitrarily). One ton of ammonium sulphate costs Rs. 315. The cost of three tons of food grains = Rs. 1215. Coefficient = $\frac{1215}{315}$ = 4.0.

The investment in irrigation is supposed to increase Rs. 107 crores in 1960 to 0.107 + $i_{31.12}$ in 1970. The over-all investment during ten year period would be (1070 + $5i_{31.21}$) and thus would give rise to an increase in output

$$\frac{125}{255}\,(1070 + 5i_{31.21}) \;=\; 2.4\, i_{31.21} + 514 \;.$$

The second five year plan mentions an increase of 3.3 million tons of food grains annually, due to other causes than fertilizers and irrigation. Agricultural extension has been regarded as the 'stimulant' creating this rise through better practices and the like.

In order to quantify the effect of extension on production, the expenditure on extension has been considered as investment (Rs. 70 crores in the final year). Expenditure increase would be from 70 to 70 + i_{34}. The resulting output increase comes to $\frac{207}{280}$ $(700 + 5i_{34}) = 3.7i_{34} + 520$. Here, too, the figure 3.3 million tons of food grains has been raised by

50 percent to account for the indirect effect.

The other three equations are

$$I = i_{28} + i_{29} + i_{34} + \sum_{j=21}^{32} n_j \tag{14}$$

(3.10) $$0 = e_{21} + e_{22} + e_{23} + e_{26} + e_{28} + e_{29} + e_{30} \tag{15}$$

$$C = c_{21} + c_{22} + c_{27} + c_{30} + c_{32} + c_{33} \tag{16}$$

n_j is the increase in stock addition in j th sector, c indicates changes in consumption and e represents the changes in net exports. The Equation 15 shows that the balance of visible trade in 1970 will be the same as in 1960.

There are 30 variables in the above-mentioned 16 equations, so we have 14 degrees of freedom. The 35 constraints were specified pertaining to three categories, investment, foreign trade and consumption. For instance the constraint on investment is

$$I \leq 0.32\ C \quad ,$$

which is based on marginal propensity to consume.

The model enables us to maximize a linear function of the variables in Equations 1 - 16. But the consumption

(c_{21}, c_{22}, c_{27}, c_{30}, c_{32} and c_{33}) were chosen as the objective criterion. The level of consumption in 1970 is, thus, maximized in the model.

To simplify the computations, the 30 model variables are not used as such. The 21 slacks and target function expressed in terms of the 14 other slacks are used for solution. Then the transformation back to the original variables has been made.

The model, as indicated by the title, may be taken as a demonstration of the application of input-output technique along with linear programming for development planning purposes. In view of the fact that the most of the input-output ratios, and capital-output ratios are based on 1953-54, makes the results of the model quite doubtful for policy purposes, especially when the economy is on the development path. The stock-output ratios are in general guesses. The model suffers from the usual criticism of proportionality of input-output model.

The Equation 13, about agriculture, is a special feature of the model. Here too the arbitrariness plays an important role in capital-output ratio.

If we compare the optimum targets to be achieved according to the model with the figures quoted by the planning commission, one may find a considerable divergence between the two. There is, however, at present no very reliable criteria to judge which of the estimates are close to reality. The increase in reliability of data and its scope would naturally improve the estimates. The attempt is worthy of praise in the sense of the methodology employed.

Desai Model

Desai (1961) formulated an input-output model closed with respect to all household and consumption, except that originating from government employees. An interesting feature of the model is that the distribution of the consumption expenditure among household groups in each processing sector, assumed to have a stable and differentiated consumption pattern, is determined endogenously.

The four processing (producing) sectors taken into analysis are (a) agriculture, (b) manufacturing, (c) services and (d) trade. There are four household sectors corresponding to each producing sector, and they derive their income from that sector only. The exogenous sectors which create demand are (a) exports, (b) capital formation, (c) government outlays, and (d) consumption expenditure of government employees. The input-output table pertains to 1950-51 and the consumption pattern for household sectors is based on data for 1952.

The processing sectors are represented by numbers

1 ... m, and the household sectors by (m+1) ... (m+m), the corresponding output for the farmer q_1, q_2, ..., q_m, and corresponding income for the latter as (q_{m+1}) ... (q_{m+m}). Then the coefficients matrix, worked out in a usual fashion, is as follows:

$$
A = \begin{array}{cccccccc}
 & 1 & & & & 2 & & \\
a_{11} & a_{12} & \cdots & a_{1m} & a_{1,m+1} & a_{1,m+2} & \cdots & a_{1,m+m} \\
a_{21} & a_{22} & \cdots & a_{2m} & a_{2,m+1} & a_{2,m+2} & \cdots & a_{2,m+m} \\
 & \vdots & & & & \vdots & & \\
a_{m1} & a_{m2} & \cdots & a_{mm} & a_{m,m+1} & a_{m,m+2} & \cdots & a_{m,m+m} \\
 & 3 & & & & 4 & & \\
a_{m+1,1} & 0 & \cdots & 0 & 0 & 0 & \cdots & 0 \\
0 & a_{m+2,2} & \cdots & 0 & 0 & 0 & \cdots & 0 \\
 & \vdots & & & & \vdots & & \\
0 & 0 & \cdots & a_{m+m,m} & 0 & 0 & \cdots & 0
\end{array}
$$

Submatrix 1 represents input-output coefficient, 2 consumption coefficients, 3 income coefficient (each household group draws income from its own sector), and 4 contains zeros, as there are no interhouse flows.

In matrix notation, the problem is formulated as

$$\theta = A\theta + Y$$

θ is the output and income matrix, and Y is the exogenous demand comprised by its different components.

The solution $\theta = (1 - A)^{-1} Y$ gives the value of m processed outputs and m household incomes for a given set of exogenous variables Y. The author suggests that the planning authority, by fixing the level of exogenous variables and their distribution among the four sectors, can know their impact on output and income of each sector. Thus the effect of alternative policy measures could be studied.

Income transfers, from one sector to another sector by such policy measures, would change the overall consumption requirements of the economy if the consumption pattern of different household sectors is different. Thus, it makes the overall consumption structure a flexible one. The accuracy of the above stated result, apart from the stability of the input-output coefficients, will depend on the stability of the consumption pattern of the household groups. The significant changes in income in one sector or in all of them, due to development in general or due to measures involving income transfers between sectors, may change appreciably the consumption pattern of concerned sectors even in a short period. Such changes, of course, will have an important impact over intermediate period. In other words, it ignores the part played by real income elasticity of demand for different goods. Such a model, based on recent data, may be useful for the study of the effect of alternative measures involving a small change in the output and income of sectors.

Palvia Model

The model suggested by Palvia (1953) is comprised of eight equations for the national economy. The two important technical equations are

$$(3.11) \quad \begin{aligned} U_1 &= h_1 \, a_1^{\frac{1}{2}} \, n^{\frac{1}{2}} \\ U_2 &= h_2 \, a_2^{0.75} \, c_2^{0.25} \end{aligned}$$

U = total product, U_1 = agricultural product, U_2 = non-agricultural product, h_1 and h_2 = constants, a = total working population, a_1 = working population employed in agriculture, a_2 = working population employed in non-agricultural sector, n = area of land qualitatively and quantitatively or land potential and c_2 = capital stock.

The elasticity of production for factors in U_1 and U_2 is a rough estimate based on the experience of other countries, and constant returns to scale are assumed. The author tries to estimate the values of instruments, namely capital needed and potential area required, under different assumptions, for attaining a certain level of national income. One can easily see from the way most of the coefficients have been estimated for the model, that the results are like 'anybody's guesses'.

Narasimham Model

A short term planning model using data of 30 variables, prices (7), quantities (7) and values (16), for the period 1919 to 1952, has been developed by Narasimham (1956). These variables have been related through five definitional equations, four demand relations, four price fixation equations, and five income formation equations.

The main purpose of the model is to assist the policy maker to determine measures and their quantities, in the short run (maybe a year) to keep the economy in line with the attainment of targets, specified for a relatively long period, say five years. These targets and corresponding instruments and their values are independent of this short run model.

IV. REGIONAL PROGRAMMING MODELS

The policy models discussed in the previous chapter, as observed, are of macro type. These have not been broken down sufficiently to sector levels, not to speak of regions. Agriculture which is the most important single industry in respect to its share of national income and of the extent of employment, has not been given due consideration in these. These models, at best, may be of some use for rough directions of some of the variables.

Tinbergen and Bos (1962, p. 10) observed:

> As a rule first stage may consist of a macro economic study of the general process of production and consumption . . . . A second stage may consist then in specifying production targets for a number of sectors over a fairly long period. A third stage if needed, may go into more details for a shorter period, giving figures for a large number of smaller sectors. A fourth stage may consist in 'filling the plan out' with individual projects . . . . The splitting up of a national program into regional programs may be the next task for development planner. Here the distance between practical possibilities and theoretical models is considerable still.

He, specifically, stressed that intermixed with this succession of stages, there may be many revisions of the previous stages, on the basis of detailed information yielded on certain aspects of the economy, as we go in the lower ladder of the disseggeration.

The main reasons for regional disaggregation either for development planning models or of general equilibrium types, may be further stated in brief as follows.

1. The results of a national analysis can be misleading, since goods and factors are not perfectly mobile. The feasible programs derived at the national level, ignoring the spatial distribution of capacity relative to output may, thus, not be practicable. This leads towards under-investment type of bias in models of accelerator type and results in shortfalls in targets.
2. Households and firms tend to concentrate their activities geographically. In the absence of transfer costs, the form of regional tendency may be mitigated, but it will still continue to operate due to other non-economic reasons. The fact is, transfer costs do exist in money, time, et cetera. The method of analysis which takes into account the inter-regional effects of changes in incomes, investment, population, is the relevant one.
3. It reduces the weighting (aggregation) problem which national input coefficients involve at different stages.

The regional studies may be divided into two groups: (a) regional input-output models and (b) inter-regional linear programming models.

Regional Input-Output Models

Just as inter-industry analysis breaks down aggregate production by commodity, so inter-regional analysis decomposes these aggregates by regions as well.

The regional input-output studies, mentioned in the following pages, may be categorized as (a) emphasizing industries and (b) emphasizing the inter-relation between agriculture and industries. The basic procedures in both types are the same. The difference lies in the emphasis given in the disaggregation of sectors.

Regional input-output models emphasizing relationship between industries

Isard (1951) formulated a theoretical model of space economy. The main analysis depends upon the input-output technique, the extension being the introduction of regions.

Let n be regions and m goods and services. Then:

$$(4.1) \qquad {}_kX_i - \sum_{L=1}^{n} \sum_{j=1}^{m} {}_{k\ell}a_{ij}\, {}_{\ell}X_j = {}_kY_i$$

${}_kY_i$ is the final demand for x_i for the k th region

${}_kX_i$ is the total product in the i th region

$$ {}_{k\ell}a_{ij} = \frac{{}_{k\ell}x_{ij}}{{}_{\ell}X_j} $$

${}_{k\ell}x_{ij}$ is the commodity i supplied from region k to ℓ for production of j th commodity there in ℓ.

The system can be solved for the autonomous change in ${}_kY_i$, to get ${}_kX_i$ in the usual input-output analysis way.

One significant feature of the model is that any good or service in a region is taken as a unique commodity, distinct from the same good or service produced in any other region. It suggests that a commodity, supplied from one region, should be considered as a different input from a similar commodity, supplied from another source, and that a separate input coefficient should apply to each. It implies that the proportions of quantities bought from other regions, as inputs for industries of a particular region, can vary with industries.

Moses (1955) developed a similar model as that of Isard (1951). He based his theoretical model on three regions and three industries. He indicated the final demand in terms of shipments on final demand account from a region, as for example

$$ Z_1^1 = Y_1^{11} + Y_1^{12} + Y_1^{13} \; . $$

The subscript indicates the commodity, and the superscripts the region. The total shipments in final demand account from Region 1 for Commodity 1, Z_1^1, are made up of Y_1^{11}, the shipments of Region 1 to itself, Y_1^{12} to Region 2 and Y_1^{13} to Region 3. Y_1^{11}, Y_1^{12}, Y_1^{13} are unknown, but Y_1^3, the demand of Commodity 1 in Region 3 for final demand sectors, is a datum. For three regions - three industries case, there are nine equations and 117 unknowns. It is assumed that the sources of supply are fixed for all uses of a given commodity in a region rather than for type of use taken by Isard (1951). For example, t_1^{13}, the proportion of Region 3's purchases of Commodity 1, which originate in Region 1, is Y_1^{13}/R^3 . Y_1^{13} is the amount of Commodity 1 bought by Region 3 from Region 1 for all industries in Region 3 and final demand sectors in Region 3. R_1^3 represents the total purchases of Commodity 1, by all industries and final demand sectors of Region 3.

On the basis of the trade coefficients such as t_1^{11}, t_1^{21}, t_1^{31}, t_1^{12}, ..., and the input-output coefficients for a region, based on output of the industry in a region and the inputs from all regions together, the input-output coefficients region-wise have been worked out for an industry. Similarly, the shipments for final demand sectors have been worked out, as for example, $Y_1^{11} = t_1^{11}\ Y_1^1$, where Y_1^1 is a datum. This procedure leaves nine equations with nine unknowns, the quantities of three products to be produced in three regions to meet the specified final demands of these commodities in different regions.

The fundamental assumptions underlying the model are the fixidity of technical coefficients, the uniformity of trading relations for all sectors in a region, and the stability of trading relations between regions.

Empirically, he tried the model with eleven industries and three regions based on 1947 data for USA. It is the first study to make systematic use of direct estimates of inter-regional trade and to test the stability of trade coefficients over 1947, 1948 and 1949. He assumes a 10% increase in all non-consumption items of final use-investment, government expenditure, and exports in Region 1, and works out the resulting production levels in each region.

Leontief (1953) divided the regional industries into regional, the output of those consumed within a region, and national, the output of those flows to other regions. Isard (1953a), based on 1939 data for USA, showed that although a considerable number of sectors can be described as local, the concept of national industry in which the pattern of supply was unaffected by the location of demand needs further refinement, as it is assumed that each producing region will continue to supply a constant proportion of demand in each consuming region.

$$a_{ik} = \frac{x_{ik}}{x_k}$$

x_{ik} as usual is the commodity i required to produce x_k; a_{ik} is, therefore, the technical input coefficient, i.e., the number of units of commodity i used per unit of output of commodity k.

$$_j\gamma_g = \frac{_jX_g}{X_g},$$

the proportion of national commodity g produced in region j. X_g is the total national output of a national commodity g.

The overall system of input-output equations for the economy as a whole,

$$(4.2) \qquad X_i - \sum_{k=1}^{m} a_{ik} X_k = Y_i$$

(i = 1, 2, ..., h(regional commodities),
h+1, ..., m (national commodities)),

can be solved for national output X_i.

The regional outputs $_jX_g$, (g = h+1, ..., m) of any national commodity can be determined by dividing the national output X_i , among regions in the same proportion as

$$(4.3) \qquad {}_jX_g = {}_j\gamma_g X_g \quad (g = h+1, \ldots, m) \quad (j = 1, 2, \ldots, n)$$

The regional output ${}_jX_L$ $(L = 1, \ldots, h)$ of regional industries, can be obtained by regional sets of equations, like the one above for each region, as for example

$$(4.4) \qquad {}_jX_L - \sum_{i=1}^{m} a_{Li}\, {}_jX_L = {}_jY_L \quad (L = 1, 2, \ldots, h) \quad (j = 1, 2, \ldots, n)$$

The proportions of inputs from all other regions in this case for national commodities would be the same for all uses in all regions. It is less restrictive for data demand, in this respect, than that of Isard (1951).

Chenery, Clark and Cao-Pinna (1953) applied input-output model to Italian economy by dividing it into two regions north and south, and a structural matrix for each of 22 industrial sectors and the household sector. They use, due to lack of data, national production coefficients to characterize production practices in each region, and allow regionally different household consumption patterns. As in the previous two models, regional flows are not disaggregated by industry of termination. He actually uses 'increamental' type of inter-regional model, where coefficients tend to be marginal coefficients, and examines the impact on two regions (and on imports) of specific investment programs (150 billion lire) in Southern Italy, the under-developed region. It has been concluded that the public investment in the south will be almost as much benefit to the north as to the south in terms of regional income generalized.

Chenery *et al.*'s model is similar in many respects to that of Moses (1955) for USA. They conclude (1959, p. 321)

> Despite the structural differences between Italy and the USA, and different composition of final demand, there is a considerable similarity in the pattern of income generation in the two analyses.

Regional input-output model emphasizing inter-relation between agriculture and industry

Schnittker and Heady (1957) made a further extension of the study by Peterson and Heady (1955) by introducing six regions, and further subdivisions of sectors. The agriculture was divided into two sectors in each region, namely crop production and livestock production. Industries were divided into six sectors at the national scale. The foreign trade, government and household sectors were included. These three have been treated as exogenous in one case, while household sector only as exogenous in the other. The total sectors including regions come to 21. The data for 1949 was used for analysis in general, but a similar analysis for 1929 was done to compare the coefficients. It has been emphasized in the study that input-output coefficients and interdependence coefficients may be taken as descriptive, describing average relations at a particular period of time, and not for prediction purposes.

Cartor and Heady (1959) expanded the input-output model to 103-order input-output matrix. Ten types of farming regions were identified. Agriculture in each region was divided into nine product groups. Industry, as in earlier models, was aggregated nationally, but into more sectors: (a) seven agricultural processing industries, (b) five agricultural furnishing industries and (c) one sector to represent 'all other industries'. The components of final demand taken were foreign trade, government, inventories and household. The analysis was based on data of the year 1954. Farm and non-farm output needed to meet projected final demand for processing industries for 1960 and 1970 were estimated.

Assumptions of Regional Input-Output Models

Regional input-output models discussed earlier are based on the assumptions stated as follows. The validity of these assumptions must be taken into account when such models are used for predictive purposes or development planning.

1. Fixity of technical coefficients for each sector in all regions: It implies (a) technology remains same, (b) constant returns to scale exists and (c) substitution possibilities are excluded for each sector in a region. It amounts to that a single production technique in each sector is employed.

   It may be relevant to mention the adjustment, in input-output model, to take into account the change in technology proposed by Carter (1958). He suggested that instead of average technical coefficient the "best technique" in each sector may be specified. The rate of adoption of technology may then be linked with the rate of investment in each sector.

2. Additivity: There are no external economies and diseconomies of scale in sectors in a region.

3. Stability in relative prices of each output produced by several regions.

4. Stability of trading relations between regions (fixed supply channels). In an immediate sense, trading pattern reflects regional cost-price relationship and regional capacities for production and distribution.

   The trading pattern will be unresponsive to shifts in regional demands if (a) regional cost of production is constant, (b) the cost of transportation of a unit of a good between every region is fixed, and (c) the supply curve of a primary factor in each region is infinitely elastic at a given regional factor price.

Moses (1955) tested the stability of regional supply coefficients. He calculated such coefficients for his first commodity groups for the years 1947, 1948 and 1949. The average change from year to year was 0.013. When 1949 coefficients were used with 1947 data, the average error in predicting the 15 total regional shipments was 4% and it was 12% for individual regional flows.

Leontief (1953) tested at the national level only the changes in input structure in USA between 1929 and 1939 and found relatively small changes. It relates to Assumptions 1 and 2 only. Similarly at the national scale, Schnittker and Heady (1957) compared the distribution of the values of important agricultural products of USA by regions for 1929 and 1949. Some significant changes in the distribution were observed.

5. Unlimited capacities: all models do not specify capacity restraints. If capacity restraints in regions do not come into force, then the predicted output may tally with the actual one, but when predictions are made for changes in final demands which surpass the present capacity restraints in relevant sectors of certain

regions, it will require some regions to draw a new source of supply for part or all of their additional requirements. This will alter trade coefficients. Some excess capacities may exist for some sectors in the short run, but it is doubtful that in all sectors and in all regions there can be excess capacities to take care of the desired changes in the final demands.

It may be argued that the capacities could be increased in the long run. This assumption is not fulfilled especially in agriculture where the land is generally fixed. Long run may be more favorable to stability of trade, where capacities can be increased, but another important factor, technological changes, generally over period do affect trading relations between regions.

6. Uniformity of trading relationships for all sectors in a region. The regional coefficients are represented by the average figure, the smaller and more homogenous is the region, the more near the reality will be the results of the model.
7. Regions as points in space: The inter-regional transport costs are ignored. A region has been taken as a point where as in reality it is a space. The decrease in size of a region as far as possible will be useful.
8. Perfect competition: (a) Any product k produced in a

region s is a perfect substitute for the k th product of any other region (except for model of Isard (1951)).
(b) At each production site of a good k, there are a large number of producers and at each consumption site, there are a large number of consumers.

In view of the assumptions, especially 1, 2, 3, 4 and 5, the models are useful to investigate the regional and inter-regional repercussions of only a small percentage of changes in the bills of goods. This is particularly true for changes which may be expected annually or over a short time span, and for group of regions which in general are not operating at full capacity. The divergence between reality and results from these models becomes greater as the magnitude of hypothetical changes increase, and as longer and long run implication of changes are sought. In the development planning, we often deal with substantial changes and over a relatively long period. A substantial emphasis is given in such planning to develop technology and its extensive adoption. The utility of such models thus becomes doubtful in such cases. However, for short run planning, these models could be applied within the framework of relatively long run development planning.

Inter-regional Linear Programming Models

In recent years, inter-regional linear programming model has been suggested. Some of the assumptions of the regional input-output model have been relaxed.

1. The assumption that each commodity is produced by one method in a region is replaced by (a) a commodity can be produced by a number of processes (finite number), and (b) each activity may have several outputs.
2. Linearity is now assumed within certain ranges, i.e. for an activity, the linear relation is changed as we go from one process to another for a commodity.
3. A separate assumption for non-negativity of activity level is needed in linear programming whereas it is automatically taken care of in input-output models.
4. Additivity is retained.
5. Trading patterns are not fixed but a part of solution.
6. Other assumptions, namely perfect competition and uniformity of relations within a region, are retained.

The basic philosophy of linear programming is to maximize (or minimize) some linear function of the activity level subject to certain linear constraints.

Algebraically, to maximize (or minimize)

$$\text{(4.5)} \quad \max: f(x) = C'X$$

subject to

$$AX \leq S \quad ,$$

where C is a column vector of weights, X is a column vector of activities (or processes) and S is a column vector of limiting constants. A is a matrix of technical coefficients, the input of a factor required per unit of an activity.

The four differences as compared to input-output type of equations are:

1. We require criterion or objective function, which enables us to choose one solution as better than another. The element of choice is, thus, introduced.
2. Alternative ways of production for the same product are introduced.
3. Primary factors, entering as restraints, are now a part of the system. In the input-output model, they were treated as exogenous and no capacity restraints were specified.
4. Restraints are inequalities than equalities in general (could be equalities).

This formulation of the problem and relaxation of some of the assumptions of the regional input-output models have given choices on demand as well as on supply side.

In an input-output model, the solutions for different assumed final demands are compared. In programming models, we treat this choice systematically through objective function and make sure that the result is indeed optimal for given conditions.

On the supply side, the choice in alternative production techniques, between imports and domestic production, between preparation of supplies from existing plants or regions, between current production and depletion of inventory, et cetera could be introduced.

In brief, regional models of input-output type assume the persistance of both existing technical coefficients and existing supply patterns, while of linear programming type, assume that the most efficient adjustment will be made to changing conditions.

The choices introduced above make this type of model useful for development planning over a relatively long period. Especially, choices over which government has some control could be employed in it. There is, however, one strong assumption that the optimum use of resources, in the economy, could be achieved either through price system or through other controls. This assumption may not be satisfied in toto but with varying degrees depending upon type of government and social and institutional constraints. This however does not blur very much the importance of the technique, as the solution gives the direction to which economy should move to achieve the objectives.

Henderson (1958), by making certain assumptions and using historical data, derived a short run optimum (minimum cost) solution for the coal industry of USA by the 'transportation' method of linear programming. He also showed that with certain necessary conditions, the optimum solution derived describes the short run equilibrium situation in a purely competitive industry. Fourteen regions were classified.

Fox (1953) applied the programming model to study the inter-regional trade in feed grain. This is similar to the above with the differences that (a) demand for feed grain in each region is assumed to be a linear function of its price and (b) production rather than capacity in each region is taken as given. Ten regions were identified. He assumed that quantities of feed and number of livestock were given, while (a) equilibrium price of feed in each region, (b) the aggregate feed trade and (c) the volume of direction of trade between each pair of possible regions were endogenous.

He summarizes his model as

Demand for feeds

$$P_c = f(q_c, Z_h^*, P_h^*)$$

Supply of feeds

(4.6)

$$Z_c^* = k$$

Equilibrium condition

$$\sum_{c=1}^{10} q_c = \sum_{c=1}^{10} Z_c^*$$

P_c is the price for feed, q_c consumption for feed, Z_h is the production of livestock in terms of grain consuming units, P_h is the price of livestock and Z_c is the production of feed. The quantities with star are fixed while others are variable.

In his subsequent study, in collaboration with Taeuber (1955), Fox used a model in which the numbers, prices, and flows of livestock as well as prices and flows of feed were dependent variables.

Moses (1960) further improved his model of 1955 by introducing capacities and relaxing the assumption of fixed trade patterns between regions. The latter modification allows for substitution of products between regions. The author blended input-output and linear programming techniques in this model.

In his theoretical model, he takes two regions and three homogeneous commodities.

Known are:

1. regional final demands Y_1^1, Y_2^1 and Y_3^1, and Y_1^2, Y_2^2 and Y_3^2

   (Subscripts denote commodity and superscripts region.)

2. regional capacities for

   a. production industries K_1^1, K_1^2, K_2^1, K_2^2, K_3^1, K_3^2

   b. transport capacity K_4^1 and K_4^2

   c. labor restraints L^1 and L^2

The problem is to minimize (labor cost of production and transport)

$$(4.7) \quad Z = \sum_{L=1}^{3} \sum_{P=1}^{2} \sum_{\Sigma=1}^{3} (a_{4i}^{P} + {}_4V_i^{Pq})\ S_i^{Pq}$$

L = 1, 2, and 3 commodities; P,q = 1, 2 regions; a_{4i} is the labor input per unit for i th output in p th region; ${}_4V_i^{Pq}$ is the labor input for transporting one unit of i th commodity from region P to q. S_i^{Pq} are shipments of commodity i from region P to q.

Restraints are 16, six for final regional demands, six for capacities of regions for production, two for transport and two for labor.

A transportation row is not added, but the transportation columns, one for each commodity in a region, are proposed. Thus trading patterns and expenditures on transportation are determined within the model rather than assumed at the outset, along with regional outputs and requirements of all goods.

Some adjustments in the empirical analysis have been made in the model due to lack of data. The labor restraints for each industry had been put in place for a region, and transport costs were taken as an exogenous sector.

The author uses a different method, the solution procedure for analysis, because the empirical analysis entailed restricted optimization and more industries could be included. In this method, as the author stated, the number of industries imposes no effective limit on the size of the system, the restraining factor being the number of regions.

Heady and Egbert (1959) used linear programming to estimate regional adjustments in grain production to eliminate surpluses. The grain production was divided into three categories as (a) feed grains (corn, barley, oats and grain sorghums), (b) feed wheat, and (c) food wheat. USA was divided into 104 regions and each region had three activities.

In matrix notation, the model is

$$\text{Minimize } f(x) = C'X$$

subject to

$$AX \leq b \; ,$$

$$x \geq 0 \; ,$$

where C is a column vector of costs (labor, power, machine, seed, fertilizer and related inputs). It is of nk order, n regions and k grain activities. X is a column vector of nk order. A is a coefficient matrix of (n+m) x (nk). It indicates the inputs required per unit of an activity and outputs produced per unit of an activity. b is a column vector of constraints of n+m order, n land restraints and m demand levels at national level.

There are 104 regional land restraints, and two demand restraints are at national level, one for feed grains and the other for food wheat. The regional land constraints are inequalities, while two demand restrictions are equalities. This specifies Model A. An adjustment in Model A was made by inclusion of rent of land as a cost item to form Model B.

Instead of using, in Model A, the costs, the net prices were also used and the problem was solved for maximization. It is assumed that differences in net prices in different regions are mainly due to transport cost involved in transfering the product to consuming regions (Model C in Heady and Egbert (1959) and Model E in Egbert and Heady (1961)). The Models A and E showed that as much as 31,951 and 28,855 thousand acres, respectively, can be withdrawn from grain acreages.

The study was further extended by Egbert and Heady (1961). In addition to three models discussed in the above study, two more models were tried.

In Model C, grain acreage in each region was divided into two components: a maximum wheat acreage and a maximum feed grain acreage. Land restraints thus were 208, in place of 104 in Models A, B and E. All other variables in Model C are the same as in Model A. In Model D, the grain components, food wheat, feed wheat, corn, oats, barley and sorghum, were included as separate activities (six activities in a region instead of three in other models), all other conditions remaining the same as in Model A.

The authors conclude that Models A, B and E yield reasonable results. These three models are in agreement for 88 of the 104 regions in retaining the grain production or shifting completely out of grain production. The disagreement in results in respect to grain production between A and E is only for six regions.

The authors are conscious of the limitations of the models in respect to the average technical coefficients for the region, insufficiency of restraints for production and consumption, et cetera.

Henderson (1957, 1959) formalized the programming problems to predict land utilization pattern for 1955 crop as follows.

$$\text{Max } \pi_i = \sum_{j=1}^{m} Z_{ij} X_{ij} \quad ,$$

where $Z_{ij} = P_{ij} Y_{ij} - C_{ij}$, expected per acre return from j th crop, i th region ($p_{ij}y_{ij}$ is the gross income and c_{ij} the cost),

subject to

$$\sum_{j=1}^{m} x_{ij} \leq a_i \quad ,$$

(4.8)

$$x_{ij} \leq a_{ij(max)} \quad , \quad j = 1, \ldots, m,$$

$$-x_{ij} \leq -a_{ij(min)} \quad , \quad j = 1, \ldots, m,$$

and $\quad x_{ij} \geq 0$.

a_i, the crop land available, and $a_{ij(max)}$ and $a_{ij(min)}$ are the maximum and minimum limits for (x_{ij}) area under j th crop in the i th region. Their maximum and minimum limits are specified on the basis of proportionate changes for each of the crops for each pair of the successive years from 1946 to

1954.

The programming problem contains m variables and 2 m+1 constraints for each region. One hundred thirty seven regions were identified, and in some regions dry and irrigated farming were separated. The classification considered 160 decision-making units (regions). The above classes were aggregated for another solution into 55. The crops considered cover 58 per cent of total value among all crops harvested in 1954.

The results from above two models were compared with estimates of crop reporting board and naive estimates. The results from 160 regions are closer to actual acreages for a larger number of crops than the corresponding crop reporting board estimates.

The special feature of the model is the specification of minimum and maximum change, in the acreage of the crops under study, which is expected to be made or will be made. These limits, maximum and minimum, are made attainable through

$$B_{ij(max)}\, x^{*}_{ij} \leq \sum_{\substack{k=1 \\ k\neq j}}^{m} B_{ik(min)}\, x^{*}_{ij} \quad , \quad j = 1, 2, \ldots, m \ ,$$

(4.9)

$$B_{ij(min)}\, x^{*}_{ij} \leq \sum_{\substack{k=1 \\ k\neq j}}^{m} B_{ik(max)}\, x^{*}_{ij} \quad , \quad j = 1, 2, \ldots, m,$$

where x^*_{ij} is the area under j th crop in the base year. B_{ij} is the proportion of change in the area of j th crop. The $B_{ij(min)}$ and $B_{ij(max)}$ are specified on the basis of changes in area between 1946 and 1954. Such extent of changes may be quite useful in the study of equilibrium but not for development planning. The planning in the less developed countries may offer wider opportunities of change than those which occurred in the past.

Two other studies bear mention here. These are by Snodgrass and French (1958) on regional production and processing flows in dairy industry, and by Judge (1956) on spatial equilibrium model for eggs.

General inter-regional linear programming models were developed by Stevens (1958) and Isard (1958). Both these models are very similar in many respects and have not been applied to empirical data. The main feature of these models is that these tend to maximize the national income of the economy as a whole, given the regional resources, regional demands and regional prices of final products. Transportation is considered as an activity like the other production activities in these models.

V. AN INTER-REGIONAL LINEAR PROGRAMMING MODEL FOR AGRICULTURAL DEVELOPMENT PLANNING IN INDIA

The purpose of this chapter of the study is to develop a theoretical model leading to optimal allocation of given resources for some specific point in time for agricultural development planning. The objectives of the development planning in general as laid down in the second five year plan (Government of India, 1956) and followed broadly also in the third plan (Government of India, 1961) are:

1. a sizeable increase in national income so as to raise the level of living in the country,
2. a large expansion of employment opportunities,
3. reduction of inequalities in income and wealth and more even distribution of economic power, and
4. a rapid industrialization with particular emphasis on development of basic and heavy industries.

The agriculture has to play an important role in meeting the first of these objectives in general and in providing food for ever-increasing population and raw materials for industries in particular.

Objectives of the Study

In order to meet the above-mentioned objectives at a specific point in time, given the supply of different resources in different regions and at a national level, and the prices of agricultural products in different regions, the theoretical model should be able to serve,

1. to find out an optimal land use pattern (cropping pattern) for different regions, consequently for the country as a whole,
2. to test how far the value of agricultural products and/or net income accruing to agricultural sector at a particular time departs from the respective attainable figures at an optimal solution,
3. to obtain an optimal allocation pattern of regional and national resources and returns which these resources would earn in different regions under competitive economy; the accounting prices of resources thus yielded could form sound bases for investment allocation among different projects in different regions,
4. to find out extent of malallocation of resources and departure between returns which the resources would earn at the optimal solution and existing returns or estimated returns of these resources,
5. to find directions to which mobile and semi-mobile resources should move in the course of time to attain the optimal allocation of resources among different regions, and
6. to estimate the adjustments required in regional set of

prices of the main agricultural products, in order to meet the minimum requirements of the products in different regions at an optimal solution.

Type of Model

An inter-regional linear programming model is proposed to be developed for the above-stated objectives. This type of model falls in between two extremes. On one end are inter-regional input-output models. They are the same as non-spatial model of Leontief except that inter-industry matrix is expanded by inclusion of inter-regional relationships. The solutions are determinate, and choices both in demand and supply sides are lacking in these types of models.

On the other end are completely flexible models of inter-regional general equilibrium type. Everything is adjusted in these according to the conditions. These models tend to extend the one point general equilibrium of Walras (1954), Hicks (1939) and others to include transport and trade variables. The addition of these variables requires corresponding additions to the equations of one point system. Such models are highly abstract, and much success has not been obtained in applying these to practical situations. Some success has been achieved in obtaining equilibrium solutions for single commodities.

The inter-regional linear programming models are less restrictive than inter-regional input-output models and less flexible than the inter-regional general equilibrium models.

The utility of the model is not limited to testing the operational efficiency of the economy in the past and at present and to form bases to put the economy in the right path of progress. With estimated prices of agricultural products and estimated supply of resources at a point of time in future, the optimal allocation of resources and the gross income and net income from agriculture could be determined for the optimal solution. It is this latter part which is particularly important for development planning over a short, medium and long periods. The model is of comparative static character and not a dynamic one in the strict sense of the word.

Basic Assumptions of the Model

1. The economy is competitive one. But it does not mean that the planner can't manipulate the prices of agricultural products. Actually, the planner can effectively determine the output of products by suitably adjusting their prices, provided he has the means to make those prices effective in the market. He, however, still allows

the competitive mechanism to determine the prices of resources and preserve the profit motive as the incentive to an individual firm.

2. The economic motive of each producer is profit maximization. Gale (1960, pp. 92-93) has concluded

> For a competitive economy in which each firm operates a set of linear activities it turns out that it is possible to assign prices to resources in such a way that, although each firm acts so as to maximize its profits, the demand for resources will not exceed the available supply. Furthermore, at these prices the firms in maximizing their own profits will automatically be operating so as to maximize the value of total output of the economy.

   The model maximizing net incomes under a competitive economy is thus consistent with maximizing gross value of products.

3. Regions are points in space. The cost of movements of products and resources within a region are not taken into account. The movements within regions could be taken into account in the model, but it would make it quite complicated and laborious. The smaller are the regions, generally, the more closely this assumption would be satisfied.

4. Agro-economic conditions, methods of farming, et cetera, are assumed uniform within regions but are different between regions. All producers in a specific production region have identical input-output coefficients and use the same productive techniques. There is thus similarity

between activities and similarity of proportions between limiting resources for production units.

5. The prices of the variable production factors are independent of the level and composition of the output of the agricultural sector.

Apart from the above conditions, the model would be subject to general assumptions of the linear programming, namely finite number of processes for producing the commodity, additivity (no external economies or diseconomies) and linearity (constant returns to scale within the relevant range, i.e. for a production process). The objective function would thus be separable, each of its components depending only on one corresponding activity level.

The Model

Let the country be divided into homogenous regions in respect to major agro-economic characteristics. Resources within a region can be further classified into different categories, to make each category as homogeneous as possible and relevant for the model. As, for example, land in a region could be divided into several classes.

It may be helpful in understanding the model, if the notations used in it, and the general set-up of the model, are explained in one place. In order to keep the model simple in notations, it is assumed that each region has the same number of resources, products, activities, et cetera.

1.	Regions	L, J	(1, 2, ..., U)
2.	Resources	b	(1, 2, ..., m)
3.	Intermediate products	i	(1, 2, ..., n)
4.	Final products	f	(1, 2, ..., q, q+1, ..., O)
	a. final products with availability constraint		(1, 2, ..., q)
	b. final products free of availability constraint		(q+1, q+2, ..., O)
5.	Production and dummy activities	j	(1, 2, ..., r, r+1, ..., p)
	a. production activities		(1, 2, ..., r)
	b. dummy activities		(r+1, r+2, ..., p)
6.	Transport activities	t	(1, 2, ..., g)

X_j^L represents the level of production and dummy activities in Region L. The production activities will include crop production, animal production, poultry raising, et cetera. The crop production activities are represented by rotations. It seems advantageous and appropriate to equate crop production activities with rotations rather than to have an activity for each crop. Crops are essentially grown in rotations in practice.

It is often likely that if appropriate restrictions on acreage of different crops are not put, the activities represented by single crops may result in such a land utilization pattern for a region which is not attainable. To put restrictions in this case would be quite cumbersome, even if it is possible to state all those relevant restrictions, which is often not the case. If the area covered in the model in a region is less than the total cropped area available, the remaining area may provide a safety valve for adjustments in case of single crops representing activities.

Each crop rotation activity may produce more than one final and intermediate product. The definition of final and intermediate products is rather restrictive here. The final products are those which are taken from agricultural sector as such. These might be used in other sectors to produce finished products. Although in broader sense, this category may be called as intermediate products, but for agriculture sector these are final products. The intermediate products here refer to those products which are produced in the agricultural sector and further consumed by the production activities in it to yield final products. There may be some products produced by production activities which are both final products (purchased from agricultural sector as such) and intermediate products (used in the agricultural sector to yield final products). In their case, for each intermediate product a dummy activity is put in the model to change its status from the intermediate to the final product.

We are faced here with another problem of joint products. A crop may be producing a primary product and a joint product. The primary and joint products may both be final products, one of these may be intermediate product or both may be intermediates.

X_t^L refers to the level of transfer activities in Region L. There will be in each region one transfer activity for transferring each mobile final product, mobile intermediate and mobile resource. Different types of transports could be combined into one for this purpose. In India, comparatively long distance movements of goods are done mostly through railways and in short distance movements of goods between regions trucks do compete with the railways. It may be possible to combine these two transport means for determining the capacity of transport at the national level and per unit cost of transporting a commodity from one region to another.

R_b^L and R_i^L indicate respectively the level of a resource and an intermediate product available in a region. These are known of the system. R_i^L by definition is equal to zero, the initial quantity of an intermediate product available in Region L. Its implications are explained later.

R_f^L refers to the availability constraints for the final products. It is the quantity of a final product which should at least be available in a region. In cases where no such minimum quantities are specified $R_f^L = 0$.

Net incomes for production, dummy and transport activities are defined as follows:

$$(5.1) \quad C_j^L = \sum_{f=1}^{0} a_{fj}^L P_{fj}^L - V_j^L ,$$

where C_j^L is net income of a production or a dummy activity. The first term on the right hand side of the equation is the gross value of final products produced per unit of j th activity in Region L. P_{fj}^L is the market price of a final commodity, and a_{fj}^L is the quantity of a final commodity produced per unit of an activity. V_j^L accounts for the variable cost per unit of an activity for those items of inputs which are not limiting and have not been included in restrictions.

A crop rotation taken as an activity would generally include more than one crop. The net income for a crop producing a single finished product is defined as

$$(5.2) \quad C_f^L = a_{fj}^L P_{fj}^L - V_f^L ,$$

a_{fj}^L is the amount of final product produced by a crop per unit of crop rotation activity, P^L_{fj} has been defined above and V^L_f is the variable cost for raising the crop.

The net income for a crop producing more than one finished product (jointly) is worked out in the same way as for an activity. a^L_{fj} would be zero in this case for all other crops within the activity except the ones under reference.

In the case of activities which produce only intermediate commodities $C^L_j = -V^L_j$. The first term on right hand of Equation 5.1 would be zero as a^L_{fj} f(1, 2, ..., 0) are zero. Similarly, if a crop within a crop rotation yields only an intermediate product $C^L_i = -V^L_i$.

C^L_j for a dummy activity converting an intermediate into a final one will be equal to P^L_f if the dummy activity unit is defined as equivalent to the unit of the intermediate product.

$$T_f^{L\to J}, \; T_i^{L\to J} \text{ and } T_b^{L\to J}$$

are the given cost of per unit of transfer activity (1, 2, ..., g) for transferring final products, intermediate products and resources respectively from Region L→J (L ≠ J). These costs include only the variable cost of the transport activities, meaning thereby the costs of resources which are limited and for which production activities compete with transport activities, are not included in it. All other relevant cost forms part and parcel of it. A unit of transfer activity is taken as equivalent to transferring of a unit of a final product or an intermediate or a resource.

Net income per unit of a transfer activity for a final product is:

$$(5.3) \quad C_t^L = C_f^J - C_f^L - T_f^{L \to J}$$

C_t^L for a final product is equal to net income for a final product in the region of destination J, $C_f^J = (P_f^J - V_f^J)$, minus the net income for that final product in the region of origin, C_f^L $(P_f^L - V_f^L)$, and minus the transport cost $T_f^{L \to J}$. It may happen that a product may not be produced at all in a region; in that case the V_f^J has to be estimated.

Net income per unit of a transfer activity engaged in transferring an intermediate product is:

$$(5.4) \quad C_t^L = - T_i^{L \to J} \quad .$$

Net income for an intermediate activity has been taken as 0 in this setting. This fact reduces the net income for a transfer activity of an intermediate product in the model to $- T_i^{L\rightarrow J}$, i.e., the variable transport cost per unit of the transfer activity (it is the negative income).

Similarly, in the case of a transfer activity relating to resources:

$$(5.5) \quad C_t^L = - T_b^{L\rightarrow J} ,$$

the variable cost per unit of transfer activity related to resources.

a_{bj}^L and a_{ij}^L are technical coefficients for resources and intermediate products for production and dummy activities. In the case of intermediates, a_{ij}^L is positive when an intermediate is an input and negative when it is an output.

a_{fj} is the amount of the finished product produced per unit of a production activity or converted from an intermediate to a final product per unit of a dummy activity.

a_{bt}^L and a_{it}^L, respectively, are a resource and an intermediate product used as a local input by a transfer activity, whereas $a_{bt}^{L\rightarrow J}$ and $a_{it}^{L\rightarrow J}$ are the amounts of a resource and an intermediate product, transferred per unit of a transport activity from Region L to J. Similarly $a_{ft}^{L\rightarrow J}$ is the quantity of a final product (f) transferred per unit of a transport activity t, from Region L to J. $a_{bt}^{'L\rightarrow J}$, $a_{it}^{'L\rightarrow J}$ and $a_{ft}^{'L\rightarrow J}$ are the corresponding amounts received in

Region J. In case, there is no loss in the quantity of a good or a resource transferred during the transfer, $a_{bt}^{L\rightarrow J} = {}'a_{bt}^{L\rightarrow J}$, $a_{it}^{L\rightarrow J} = {}'a_{it}^{L\rightarrow J}$ and $a_{ft}^{L\rightarrow J} = {}'a_{ft}^{L\rightarrow J}$.

Finally, a_t^L are the units of transport used by a transport activity t in Region L.

In order to represent the relations of the model clearly, it may be desirable to consolidate the notations explained in the foregoing pages in tabular form. This has been done in Table 13 where the model is stated in matrix notations.

The objectives set out for the study would be met by the formulation of the problem as follows.

Direct problem

$$(5.6) \qquad \text{Max: } \sum_{L=1}^{u} \sum_{j=1}^{p} C_j^L X_j^L + \sum_{L=1}^{u} \sum_{t=1}^{g} C_t^{L\rightarrow J} X_t^L$$

It is the maximization of net income of the regions from agriculture and subsequently of the country as a whole from agriculture, taking into account inter-regional flows of the commodities, with given transport facilities. The objective function is separable.

The above maximization is subject to the following constraints (regional and national).

Resources

$$(5.7)\quad \sum_{j=1}^{r} a_{bj}^{L} X_{j}^{L} + \sum_{t=1}^{g} a_{bt}^{L} X_{t}^{L} + \sum_{t=1}^{g} a_{bt}^{L\to J} X_{t}^{L}$$

$$- \sum_{\substack{L=1\\ L\neq J}}^{u} \sum_{t=1}^{g} a_{bt}^{J\to L} X_{t}^{J} \leq R_{b}^{L} \quad ,$$

b(1, 2, ..., m)

Intermediate products

$$(5.8)\quad \pm \sum_{j=1}^{p} a_{ij}^{L} X_{j}^{L} + \sum_{t=1}^{g} a_{it}^{L} X_{t}^{L} + \sum_{t=1}^{g} a_{it}^{L\to J} X_{t}^{L}$$

$$- \sum_{\substack{L=1\\ L\neq J}}^{u} \sum_{t=1}^{g} a_{it}^{J\to L} X_{t}^{J} \leq 0 \quad ,$$

i(1, 2, ..., n)

Final products

$$(5.9)\quad - \sum_{j=1}^{p} a_{fj}^{L} X_{j}^{L} + \sum_{t=1}^{g} a_{ft}^{L\to J} X_{t}^{L} - \sum_{\substack{L=1\\ L\neq J}}^{w} \sum_{t=1}^{g} a_{ft}^{J\to L} X_{t}^{J}$$

$\leq \; - \, R_f^L \; ,$

$f(1, 2, \ldots, 0)$

Transport

$$(5.10) \quad \sum_{\substack{L=1 \\ L \neq J}}^{u} \sum_{t=1}^{g} a_t^{L \to J} \, X_t^L \; \leq \; R_h$$

$$(5.11) \quad X_j^L \, , \; X_t^L \; \geq \; 0$$

The explanation of restrictions may be in order.

In the case of resources the constraints read horizontally term by term: (1) amount of a resource used by all the production in a region, and (2) resource used as local inputs by the transfer activities of a region. In the case of immobile resource, the sum of first two terms should be less than or equal to ($\leq$) the amount of resource R_b^L available.

In the case of a mobile resource, the third and fourth terms won't be zero. The third term indicates the amount of resource exported to other regions, and the fourth term shows the quantity of total receipts of a resource from other regions; the latter term is negative. The sum of all the four terms in this case should be $\leq R_b^L$. The resources would include all resources such as land, labor, capital, irrigation, fertilizer, et cetera.

In the case of intermediate products, the first term horizontally shows the quantities of an intermediate product produced by production activities, converted by dummy activities into a final product and the intermediate products used by production activities. The inputs are in this case indicated by (+) and outputs as (-). The second term, as in the case of resources, accounts for the local inputs for transfer activities of a region. The third and fourth terms would be zero for immobile intermediates. Thus, the sum of the first two terms should be ≤ 0.

Let us first discuss the case where an immobile intermediate product does not fall into the category of a final product. If the quantities produced of an intermediate product i by different production activities (quantities with negative sign in the first term) are transposed to right hand side of 5.8, the meaning of the constraint becomes quite clear. It states that requirements of an intermediate commodity i by production activities and by transport activities as local inputs, must not exceed the output of i. It bears mention here that in the case of intermediate products which are produced as a single output of an activity or a sub-activity, the equality will hold in the optimal solution. Demand for an intermediate will be equal to its production.

The intermediate products would be using, in addition to the variable costs, the scarce resources in their production; the excess product would therefore be inconsistent with an optimal solution.

Some of the intermediate products may be produced jointly along with final products. In their case, the inequality sign can hold at the optimal solution. The production can exceed requirements of production activities and of transport activities for local use. Levels of activities producing an intermediate product as a joint product with finished products are determined by the net incomes of activities and their requirements of scarce resources in addition to the demand of an intermediate commodity by production and transport activities for local inputs.

In the case of mobile intermediates, the third term in 5.8, as in the case of resources, indicates dispatches to other regions and fourth one as receipts from other regions. The results indicated above in respect to the inequality would be true in their case as well.

In case an intermediate product happens to be a final product as well, the excess production over and above demanded by production activities and by transport activities as local inputs for immobile intermediate will be transferred to the final product by a corresponding dummy activity. a^L_{fj} for the final product will be negative and a^L_{ij} for respective intermediate product will be positive in the dummy activity ($|a^L_{ij}| = |a^L_{fj}|$). No upper limits have been specified for final products in the system. The equality sign will be satisfied by an intermediate product i with positive level at the optimal solution in 5.8. In the case of mobile intermediate, the dispatches from and receipts to a region of i are to be accounted for in the above relation.

Constraints of the type 5.9 need special attention. These are generally referred to as availability constraints. These are included in a system of constraints in order to insure the availability of specified minimum quantities of some goods in different regions. One constraint pertains to the minimum level of requirements of a good in a region. It may be pertinent to specify the minimum level of certain food grains needed in a region, based on the number of inhabitants and their consumption habits. Similarly, these constraints may refer to raw materials required to keep the factories in operation in a region. It bears mention that if these constraints do not form a part of the system, it may happen that there may be a dire scarcity of certain goods in some regions and a glut of supplies of some of these in some others at an optimal solution.

Inequality sign to meet the minimum requirements of a good in a region would be greater than (>); to make it consistent with other inequality signs less than (<) in a maximization problem, both sides of the inequality are multiplied by -1. Now it reads as $\leq -R_f^L$, where R_f^L is the minimum amount of a final good f required in a Region L. Wherever no minimum amounts are specified $R_f^L = 0$.

The first term on the left hand side of Constraint 5.9 is the amount of the commodity (f) produced by all the production activities and converted from an intermediate product to a final by dummy activities. The second term pertains to exports to other regions and the third one receipts from other regions. The second and third terms would be zero in the case of an immobile final product.

These constraints play a special role in our problem by indicating extents by which given prices of products at the beginning need to be adjusted in different regions, to bring these in line with the prices of other commodities in the competitive economy. Further details in this respect are discussed under dual. One may even think of putting the availability constraints at the national level for some goods, especially for those ones required for export purposes. Even in their case, these constraints could be split up for regions from where exports take place. In the case of more than one exporting place for such goods, the regional availability constraint could be specified by taking into account the facilities for exports in a region. If the regional constraints pertaining to exporting facilities are not relevant, the availability constraint for such cases can be put at the national level.

The specification of minimum availability level of certain goods for a region is not arbitrary. These are related to their respective prices in a region. In case the model is run for the past, the prices ruled in a region and the corresponding commodities bought are known. These quantities could be used directly for constraints. In the case of current and future periods, the estimated prices of goods would be used. In that case, some approximation of demand function would be needed to relate the amounts specified for availability constraints with the estimated prices. As a first approximation, the demand function may be taken as a linear one for a relatively short period over a relevant range. This relevant portion of the demand function may be estimated from the relation between quantities bought and prices obtaining over some past years in a region. In case of relatively long periods involving violent changes in prices and incomes, a more complicated relation, based on projections of demand and supply, would be needed to estimate the level of availability constraints.

There may be some final products for which there is no need to specify the minimum amounts to be made available in some regions or all regions. In such instances, R_f^L is zero. It ensures that the quantities exported of that final product from a region to other regions can't be greater than the quantity available in that region. The quantity available will be equal to the amount produced in a region as a region is not allowed to export and import the same product at the same time.

Constraint 5.10 is at the national level. It states that transport units used by all the transfer activities of different regions should not exceed the capacity of transport R_h. If the model is run excluding this constraint, all other conditions remain the same, the total requirements of the transport facilities at the optimal value of the objective function could be determined. This information would be useful in planning for the transport system of the country.

It may be noted that model is bounded on both ends. At one end, are resources restrictions and at the other end, are availability constraints. If there are not sufficient resources to meet the minimum specified requirement of certain goods, it would be indicated by a failure to find out non-negative values of the choice variables in the objective function. One should not stipulate such amounts which can't be met by the program.

Now suppose, no availability constraints are defined in a model either at the regional or national levels for any final products. The maximization, unrestricted except resources, intermediates and transport, would give an efficient solution where output of any one final good cannot be increased without a commensurate decrease in the output of others, and this would result in the decreasing of the value of the objective function at given sets of C_f^L and C_t^L. Thus an efficient solution guarantees efficient allocation of resources with respect to the set of market prices assumed for final products and variable factors. But it does not ensure in any way an optimal allocation of goods among regions. It may happen that the goods would tend to flow to high net income (prices) regions, while leaving the other regions without the bare minimum requirements.

Once we obtain such a solution, we may alter the prices and rework the problem again to obtain a more satisfactory distribution of goods. But this could be approached more easily by specifying availability constraints, and then readjusting prices if required, as discussed in the dual later. The maximization without availability constraints can, of course, give some idea of long run adjustment required to be made in regional transfer of population, location of industries, etc.

It may be noted that specifying the availability constraints, is expected to decrease the value of the objective function, and thus the solution may be called as semi-efficient.

There will be two possible cases when the inclusion of minimum consumption constraints will still allow an efficient solution: (a) In cases none of the regional availability constraints mentioned as 5.9 are effective and (b) there exists multiple optimum solutions of the efficient program, at least one of which is fulfilling all the availability constraints.

If it is found that the income accrueing to certain regions has fallen below the minimum desired level at the optimal solution, the relevant restrictions may then be included in the program itself. These restrictions actually are included in programs stated in Chapter VII.

Dual

It may be relevant to state the relationship between primal problem and its dual.

1. The dual of a maximum problem is a minimum problem and vice versa.
2. The sense of inequalities in the constraints of the primal and its dual are the reverse of each other. In a maximizing system, the inequality sign is less than (<) and in the minimum system it is greater than (>) in all constraints. This rule holds except that the inequalities pertaining to non-negative values for the choice variables, which have the same sense in the direct and

the dual.

3. There are as many constraints in the dual as there are choice variables in the original problem. The constants of the objective function of the primal problem appear as the constant terms of the constraints of the dual.

   In our maximizing problem, C_j^L and C_t^L which occur as coefficients of the objective function, become each a limiting constant in a constraint of the dual.

4. The dual has as many choice variables as there are constraints in the original problem. The objective function of the dual thus has one choice variable for each constraint of the primal problem and vice versa.

   In the problem under reference, as indicated in the following pages, R_b^L, a_i^L, R_f^L and R_h are coefficients of the objective function of the dual and w_b^L, $\bar{p}_i^L$, $\bar{p}_f^L$ and $\bar{p}_t^L$ are the choice variables respectively in it.

5. The coefficients of a single choice variable in the constraints of the original problem become the coefficients of a single restraint in the dual. In the matrix notation, the coefficient matrix of restraints of the dual is the transposed of that of the restraints of the original problem, and vice versa.

6. Fundamental Duality Theorem: If a standard maximum or minimum problem and its dual are feasible, then both have optimal solutions and both have the same value. If either

is not feasible, then neither has an optimal value.

It is evident from the above theorem that a primal, and hence its dual as well, has optimal solution if and only if both have feasible solutions. If only one problem has a feasible solution, then its objective function is unbounded.

At the optimal solutions for the primal and dual, which are equal, the constraints obeying the inequality sign less than in the primal problem of maximizing have a zero coefficient in the objective function of the dual. It shows that the constraint is not binding.

In our problem, the constraints R_b^L, O_i^L, R_f^L and R_h which obey the inequality less than at the optimal solution of the maximizing problem will have zero coefficients in the objective function of the dual. It means unless the whole supply of a resource is used, it won't earn any return. Similarly, the constraints having inequality sign greater than in the minimization dual optimal problem will have zero coefficients in the (maximization) direct optimal solution. It says that if the cost of an activity exceeds the income derived from it, it will be operated at a zero level. As in the primal case, the constraint is non-binding.

Binding constraints (meeting the equality sign) in the primal or dual optimal solutions will usually have positive corresponding choice variables, but it is not always true. If the equality sign is satisfied in the optimal dual solution for an activity, the choice variable in some cases in the primal optimal solution may be zero and not positive. It indicates that there are more than one optimal solutions with identical values. The activity satisfying the equality sign in the optimal dual solution, run at a zero level in the given optimal solution, could be operated at positive level in one or more optimal solutions.

In the same fashion, if there are more than one optimal solutions for the dual, at least one binding constraint in the optimal primal problem will have a zero choice variable in the dual.

The above-mentioned two conditions pertaining to inequalities of constraints of maximum problem and its dual (minimum) at the optional solution, are referred to as an equilibrium theorem (Gale, 1960). The second condition $\geq$ in the dual of the primal of maximizing net income of firms may be thought of stability conditions in the sense that the income level (value of the program) can't be increased by changing activity levels given the constants of the problem. The first condition $\leq$ in the primal, too, is a sort of stability condition, as for resources (goods) for which given supply at the beginning is not exhausted in the optimal solution, will have zero return or price--a free good.

The second condition refers to prices (returns) to constraining resources or goods, whereas the first condition relates to activity levels. It may be stated that these equilibrium conditions are somewhat different from the 'general equilibrium' in the sense of Walras (1954), which would determine the prices of consumer goods as well as resources. Here the prices of consumer goods are given, the returns to resources are determined for a competitive economy leading to the optimal allocation of resources. In our model, as will be observed later, the prices of the final goods could be adjusted to meet the minimum availability constraint in different regions of the primal problem. The policy maker has also a choice to adjust the prices of agricultural commodities to the extent he can make them effective in the market through price controls, monetary and fiscal policies, et cetera.

According to the rules of the dual, its objective function and restrictions are stated below:

$$(5.12)\quad \text{Minimize:}\ \sum_{L=1}^{u}\sum_{b=1}^{m} W_b^L R_b^L + \sum_{L=1}^{u}\sum_{i=1}^{n} \bar{P}_i^L O_i^L$$

$$- \sum_{L=1}^{u}\sum_{f=1}^{q} \bar{P}_f^L R_f^L + \bar{P}_t R_h$$

where W_b^L, $\bar{P}_i^L$, $\bar{P}_f^L$ and $\bar{P}_t$ are return to a resource, imputed value of an intermediate, price adjustment factor-subsidiary prices (Isard and associates, 1960, p. 465) for commodities for which availability constraints are effective, and imputed return to the transport service for being scarce. The imputed return to transport $\bar{P}_t$ is in addition to the $T_f^{L\to J}$, $T_i^{L\to J}$, and $T_b^{L\to J}$, the given in the system; as in case of final products $\bar{P}_f^L$, the subsidiary price, is in addition to P_f^L, the market price of a final product in Region L.

The objective function is to minimize the imputed or fictitious returns to resources including transport, after deduction of subsidy payments necessary to achieve the required availabilities of finished goods for which availability constraints have been specified in different regions. The subsidy payments are made clear in the following pages. The second term in the objective function is zero, but $\bar{P}_i^L$ has a meaning. It is the imputed price for an intermediate product in a region.

The above function is subject to constraints as:

<u>Production</u>

$$(5.13) \quad \sum_{b=1}^{m} a_{bj}^L\, w_b^L \pm \sum_{i=1}^{n} a_{ij}^L\, \bar{P}_i^L - \sum_{f=1}^{q} a_{fj}^L\, \bar{P}_f^L \geq C_j^L$$

$j(1, 2, \ldots, p)$

Transport activities

Final product

$$(5.14)\quad \sum_{b=1}^{m} a_{bt}^{L} w_{b}^{L} + \sum_{i=1}^{n} a_{it}^{L} \bar{P}_{i}^{L} + a_{ft}^{L\to J} \bar{P}_{f}^{L} - a_{ft}^{\prime L\to J} \bar{P}_{f}^{J}$$

$$+ \sum_{b=1}^{m} a_{bt}^{J} w_{b}^{J} + \sum_{i=1}^{n} a_{it}^{J} \bar{P}_{i}^{J} + a_{t}^{L\to J} \bar{P}_{t}$$

$$\geq C_{t}^{L}(C_{f}^{J} - C_{f}^{L} - T_{b}^{L\to J})$$

Intermediate product

$$\sum_{b=1}^{m} a_{bt}^{L} W_{b}^{L} + \sum_{i=1}^{n} a_{it}^{L} \bar{P}_{i}^{L} + a_{it}^{L\to J} \bar{P}_{i}^{L} - a_{it}^{\prime L\to J} \bar{P}_{i}^{J}$$

$$+ \sum_{b=1}^{m} a_{it}^{J} W_{b}^{J} + \sum_{i=1}^{n} a_{it}^{J} \bar{P}_{i}^{J} + a_{t}^{L\to J} \bar{P}_{t} \geq - T_{i}^{L\to J}$$

Resource

$$a_{bt}^{L\to J} W_{b}^{L} - a_{bt}^{\prime L\to J} W_{b}^{J} + a_{t}^{L\to J} \bar{P}_{t} \geq - T_{r}^{L\to J}$$

(No other resource except transport or product is assumed to be employed for the transfer)

(5.15) $W_b^L, \bar{P}_i^L, \bar{P}_f^L, \bar{P}_t \geq 0$

Crop production activities are represented in the model by crop rotations. A crop in a rotation is termed as a sub-activity. Each crop production activity may thus yield more than one final product or more than one intermediate product or some combination of final products and intermediate products. A sub-activity may be producing a single final product or a single intermediate product, or jointly a final product and an intermediate, or two intermediate products. There is also a possibility, though often it may not happen, that more than one final products or intermediate products, or some combination of these may be produced by a sub-activity.

A crop (sub-activity) may be included in more than one activity. Thus the same final product or intermediate product or a combination of final product and intermediate or a combination of intermediate products may be produced by more than one activity. The livestock production activities may also exhibit the relations expressed for crop production activities.

It may be relevant now to examine the implications of the relationships represented by constraints pertaining to production activities. A regional constraint for a production activity states that the imputed costs of scarce resources employed minus the imputed value of intermediates produced and plus the imputed value of intermediates used, and minus the subsidy payments for final products (with limiting availability constraints) per unit of an activity must be greater than or equal to the net income C_j^L of an activity. The production activity for which inequality holds good won't be present in the optimal solution. Unless there exists multiple optimal solutions, all activities for which equality is satisfied will be at a positive level at the optimal solution. The above relations hold true for a sub-activity within an activity.

Resources for which complete utilization is not there, w_b^L will be zero. Similarly, $\bar{\bar{P}}_f^L$ will be zero for non-binding availability constraints. The implications of $\bar{\bar{P}}_i^L$ are discussed in detail under constraints for intermediate products.

It may be relevant to study the relationship for a final product in Constraint 5.13. A final product may be produced by a number of activities, but let us assume it is produced as a single product by these. In the optimal solution 5.16 holds.

$$(5.16)\quad \sum_{j=1}^{P} \sum_{b=1}^{m} a_{bj}^L W_b^L + \sum_{i=1}^{n} a_{ij}^L \bar{\bar{P}}_i^L - \sum_{j=1}^{P} a_{fj}^L \bar{\bar{P}}_f^L$$

$$= \sum_{j=1}^{P} C_j^L \quad , \quad (C_j^L = C_f^L)$$

a_{bj}^L and a_{ij}^L will be zero everywhere except for the activity or sub-activity engaged in producing the final product, f. Similarly, corresponding C_j^L will be zero for those activities which are not producing f.

The above relation would be simplified if it is further assumed that only one activity or a sub-activity produces the final product, f, as a single product, and does not use any intermediate product. The latter assumption can be easily relaxed wherever necessary with retaining the term $\sum_{i=1}^{n} a_{ij}^L P_i^L$ on left hand side in Equation 5.16. It corresponds to imputed returns to intermediates used as inputs.

Equation 5.16 now reduces to:

$$\sum_{b=1}^{m} a_{bj}^L W_b^L - a_{fj}^L \bar{P}_f^L = C_f^L$$

The above equation can be written in the form

$$K \sum_{b=1}^{m} a_{bj}^L W_b^L - \bar{P}_f^L = K C_f^L \quad , \quad \text{where } K = \frac{1}{a_{fj}^L}$$

(5.17)

$$K \sum_{b=1}^{m} a_{bj}^{L} W_{b}^{L} = K C_{f}^{L} + \bar{P}_{f}^{L}$$

It states that the cost imputed to scarce resources per unit of final commodity, f, should be equal to net income K C_f^L plus the imputed price to be paid to make the minimum quantity of a final good available in a region. $\bar{P}_f^L$ has been termed as the subsidy price. It is amount which must be paid to producers in order to make them supply the required amount of a final product in a region.

In case the intermediate products are used as inputs, left hand side of Equation 5.17 will include

$$\sum_{i=1}^{n} a_{ij}^{L} \bar{P}_{i}^{L} \quad .$$

It may be noted that this subsidy price is imputed back to resource owners as indicated in the above relation. The question as to who should pay this subsidy price ultimately is examined later.

Competitive prices of the intermediate products is one of the important information which the model generates. The relationships, giving the imputed price of an intermediate product produced under different conditions, are stated as follows.

Starting with a simple case, it may be assumed that a pure intermediate product (not classified as final as well) is being produced by a single activity or a sub-activity and does not use any intermediate product as an input. The following equality will hold for these intermediate products at positive level at the optimal solution:

$$\sum_{b=1}^{m} a_{bj}^{L} W_{b}^{L} - a_{ij}^{L} \bar{P}_{i}^{L} = - V_{j}^{L}$$

(5.18)

$$K \sum_{b=1}^{m} a_{bj}^{L} W_{b}^{L} + K V_{j}^{L} = \bar{P}_{i}^{L} \quad , \text{ where } K = \frac{1}{a_{ij}^{L}}$$

It states that the imputed price $\bar{P}_{i}^{L}$ of an intermediate product i is equal to the imputed value of resources employed and variable cost involved in producing per unit of intermediate product i. The excess production will not be there for i under these conditions. $\bar{P}_{i}^{L}$ will, therefore, be positive.

Let the assumption of not using any intermediate product as an input be relaxed in the aforementioned case, but other conditions remaining the same, then

$$(5.19) \quad \sum_{b=1}^{m} a_{bj}^{L} W_{b}^{L} + \sum_{i=1}^{n} a_{ij}^{L} \bar{P}_{i}^{L} + V_{j}^{L} = a_{ij}^{L} \bar{P}_{i}^{L}$$

$\bar{P}_i^L$ for intermediates used as inputs but singly produced will be greater than zero. $\bar{P}_i^L$ for intermediate inputs produced jointly may be zero or greater than zero. The relations determining the $\bar{P}_i^L$ for intermediates produced as joint products are explained later.

The relation for an intermediate product produced as a single output by a number of activities would stand as:

$$(5.20) \quad \sum_{j=1}^{p} \sum_{b=1}^{m} a_{bj}^{L} W_{b}^{L} \pm \sum_{j=1}^{p} a_{ij}^{L} \bar{P}_{i}^{L} = - \sum_{j=1}^{P} V_{j}^{L}$$

a_{bj}^{L} and a_{ij}^{L} will be zero everywhere except for activities producing intermediate product i. Similarly V_j^L will be zero for such activities.

Joint products either as outputs of an activity or intermediates used as inputs have not been discussed. The interpretation becomes rather complicated in the case of joint products where either an intermediate product is produced jointly with a final product or with another intermediate product. In these cases, the production of i can exceed the requirements for it in the system, as discussed earlier. It may again be noted, this statement refers to pure intermediate products which are not classified as final products as well, otherwise the excess production will be converted to the final products by dummy activities.

An intermediate product jointly produced with a final product will have $\bar{P}_i^L = 0$, in case of excess production over requirements. The variable cost and imputed cost of resources and of intermediates for such an activity will be borne by the final product. But, in cases, the production of i is not greater than its requirements in the system, $\bar{P}_i^L$ will not be zero. Then the imputed cost to scarce resources and intermediate products employed plus variable cost will be equal to the value of the final product produced plus the imputed value of an intermediate produced per unit of an activity entering in the optimal solution.

$$\sum_{b=1}^{m} a_{bj}^L W_b^L + \sum_{i=1}^{n} a_{ij}^L P_i^L - a_{ij}^L P_i^L = a_{fj}^L P_f^L - V_j^L$$

(5.21)

$$\sum_{b=1}^{m} a_{bj}^L W_b^L + \sum_{i=1}^{n} a_{ij}^L \bar{P}_i^L + V_j^L = a_{fj}^L P_f^L + a_{ij}^L \bar{P}_i^L$$

If the final product is also subject to availability constraint, the corresponding term for subsidy payments can be easily included in the above-stated equation. The relations referred to above are useful for apportioning the technical coefficients and variable cost for an activity to the primary and the joint product in the ratio of $a_{fj}^L P_f^L$: $a_{ij}^L \bar{P}_i^L$ (in proportion to the gross values of the products).

In cases where more than one intermediate products are jointly produced by an activity or a sub-activity at the optimal solution, the relation is as follows:

$$\sum_{b=1}^{m} a_{bj}^{L}\, W_{b}^{L} + \sum_{i=1}^{n} a_{ij}^{L}\, \bar{P}_{i}^{L} - \sum_{i=1}^{n} a_{ij}^{L}\, \bar{P}_{i}^{L} = - V_{j}^{L}$$

(5.22)

$$\sum_{b=1}^{m} a_{bj}^{L}\, W_{b}^{L} + \sum_{i=1}^{n} a_{ij}^{L}\, \bar{P}_{i}^{L} + V_{j}^{L} = \sum_{i=1}^{n} a_{ij}^{L} \bar{P}_{i}^{L}$$

If all intermediate products produced as outputs in the above relation, except one of the intermediate products jointly produced, are in excess production, then the above relation is reduced to 5.19. All $\bar{P}_{i}^{L}$ except the one on the right hand of the equation will be zero. In case more than one $\bar{P}_{i}^{L}$ on right hand side of equation is positive, additional relations will be required to determine the $\bar{P}_{i}^{L}$ uniquely. A set of equations embracing the relevant intermediate relationships between intermediate products jointly produced, and having the same number of equations as $\bar{P}_{i}^{L}$ unknown, will serve the purpose.

It may happen that an intermediate product is also a final product. The possibility of excess production for intermediate products jointly produced in such situations is ruled out in the model. The additional production over requirements of the system would be transferred to the final product.

The imputed price of intermediate product will be equal to the given price of the respective finished product, plus the subsidy price for the final product (if the corresponding availability constraint is binding).

$$a_{ij}^{L}\,\bar{P}_{i}^{L} - a_{fj}^{L}\,\bar{P}_{f}^{L} = C_{j}^{L} \quad , \quad a_{ij}^{L} = a_{fj}^{L}$$

If the unit of dummy activity is defined as equal to the unit of the intermediate product or the above equation is divided by a_{ij}^{L}, then

$$\bar{P}_{i}^{L} - \bar{P}_{f}^{L} = P_{f}^{L} \quad , \quad C_{j}^{L} = P_{f}^{L} \cdot a_{fj}^{L}$$

(5.23)

$$\bar{P}_{i}^{L} = P_{f}^{L} + \bar{P}_{f}^{L}$$

$$\bar{P}_{i}^{L} = P_{f}^{L} \quad , \quad \text{if } \bar{P}_{f}^{L} = 0$$

$\bar{P}_{i}^{L}$, as explained earlier, equals the imputed cost of inputs of scarce resources and intermediates.

The above-mentioned relations can be incorporated easily in the relations for final products, where it was assumed that an activity only produced a final product and does not either produce an intermediate and/or employ in its production an intermediate product.

The system yields the competitive level of prices of intermediate products in different regions. Lack of these prices has been seriously felt in a number of research studies, especially for those intermediate products which generally do not enter the market for exchange, as for example fodder. Once the imputed prices of intermediate products are known, input coefficients and variable costs for an activity producing a final and an intermediate product can be allotted in the ratio of the gross value of the final product and imputed value of an intermediate product yielded by the activity.

The above-mentioned relations for activities producing final and intermediate products would be true both for mobile and immobile commodities. The transfer activities will play their part in determining the production pattern of regions as explained below in the case of mobile products.

The examination of Restriction 5.14 for a mobile final product shows that the value of the local inputs of scarce resources and intermediates used by a transfer activity in the region of origin and destination for loading, unloading, et cetera plus the subsidy payment if any for that commodity in the region of origin, minus the subsidy payment if any in the region of destination, and plus the imputed value of transport for its scarcity, should be greater than or equal to C_t^L.

Again to make the exposition more clear let us assume that no scarce factors and/or intermediates are used either in the exporting region or receiving region by an active transfer activity (or all transport costs have been included in $T_f^{L\to J}$), further that $a_{ft}^{L\to J} = {}'a_{ft}^{L\to J} = 1$ unit of a final product, and transport is not limited, meaning thereby $\bar{P}_t = 0$, then:

$$\bar{P}_f^L - \bar{P}_f^J = C_t^L \, (C_f^J - C_f^L - T_t^{L\to J})$$

(5.24)

$$\bar{P}_f^L + C_f^L + T_f^{L\to J} = C_f^J + P_f^J$$

As indicated earlier, $\bar{P}_f^L + C_f^L$ is equal to the cost imputed to the scarce resources in Region L for producing a unit of commodity f ($\bar{P}_f^L$ is the subsidy price and C_f^L is the net income). Same is the interpretation for the values of Region J.

The commodities for which the equality sign holds good will enter in the active transfer activities. It may be noted that though C_f^L and C_f^J are constants, $\bar{P}_f^L$ and $\bar{P}_f^J$ are variables in cases where the availability constraints are effective, otherwise these are zero. Even if the availability constraint is effective in one region between a pair of regions, it would tend to satisfy the equality sign in the above-stated constraint. It would mean that cost imputed to scarce resources for producing a unit of final product in two regions would differ only by the variable transport cost $- T_f^{L \to J}$; the cost being lower by $- T_f^{L \to J}$ in the region of origin (L) than in the region of destination.

In instances where either the availability constraints in both regions are not stated or are not finding, $\bar{P}_f^L$ and $\bar{P}_f^J$ are zero. The remaining terms in the above restrictions are constant. It is possible, therefore, that for some active transfer activities equality sign may not be satisfied. In these cases $C_f^L + T_f^{L \to J}$ may be less than C_f^J, the commodity if produced in L will flow to J. In other words, the absolute difference between the net income of a mobile product in such instances can be greater than the variable transport cost.

If for argument we assume that the variable costs are equal for a mobile final product in a pair of regions, the adjusted price, $P_f^L + \bar{P}_f^L$ in Region L plus the variable transport cost $T_f^{L \to J}$ for the final product is equal to the adjusted price, $P_f^J + \bar{P}_f^J$, in Region J, in cases where out of pair of regions, in one region $\bar{P}_f$ is not zero. The adjusted prices are variable in a sense. Each is a sum of constant (the pre-assigned final product price) plus a variable part (the variable subsidy price) depending upon the amount of effective availability constraint.

As in the case of a final product, we may assume for an activity engaged in transferring an intermediate from Region L to J, that $a_{it}^{L\rightarrow J} = a_{it}^{\prime L\rightarrow J} = 1$ unit of an intermediate product, and the transfer activity neither uses any resources and/or intermediates in the region of source or destination. These assumptions reduce the relationship as:

$$\bar{P}_i^L - \bar{P}_i^J = - T_i^{L\rightarrow J}$$

(5.25)

$$\bar{P}_i^L - T_i^{L\rightarrow J} = \bar{P}_i^J$$

It shows that for a mobile intermediate, the imputed price would vary in two regions by the amount of variable transport cost required to shift an intermediate from one region to another. $\bar{P}_i^L$ and $\bar{P}_i^J$ are variable, therefore equality sign would hold for each intermediate entering as transfer activity in the optimal solution at positive level.

Transfer activities further influence the production pattern of regions by transferring mobile resources from regions of lower returns to those of higher returns. If a primary resource is mobile under the same assumptions of final and intermediate products, the relation at the optimal solution is:

$$(5.26) \quad W_b^L - W_b^J = C_t^L$$

Let b be labor and W_b^L and W_b^J the imputed value marginal productivity of labor in Regions L and J. C_t^L is the net income per unit of transfer activity; the unit is per person. There is a choice in determining C_t^L, depending on what difference is to be tolerated in the marginal value productivity of a resource between a pair of regions. Corresponding to the final activity,

$$C_t^L = W'^J_b - W'^L_b - T_b^{L \rightarrow J}$$

W'^J is the institutional wage rate (prevailing wage rate) in Region J, and W'^L, the prevailing wage rate in Region L. The prevailing wage rates have been found to be higher than marginal value productivity of labor in under-developed countries, especially in agriculture, possibly due to self employment on the farm for a majority of cultivators. $T_b^{L \rightarrow J}$ is the direct cost (fare) of moving a person from Region L to J.

W'^J_b and W'^L_b may be controlled to a large extent by the government through minimum wage legislation and other wage control measures.

It may be interesting to examine the implications of specifying different values of C_t^L.

(a) $\quad C_t^L = - T_b^{L \to J} \quad , \quad \dot{W}_b^L = \dot{W}_b^J$

Then, (5.26)

$$W_b^L - W_b^J = - T_b^{L \to J}$$

$$W_b^L + T_b^{L \to J} = W_b^J$$

The marginal productivity of labor would differ in a pair of regions by the cost of transfer $T_b^{L \to J}$ of labor. The labor would move from a region of low marginal productivity (L) to the region of a higher marginal productivity (J), unless the equality in the above relation is reached. At that point $\dot{W}_b^L$ and $\dot{W}_b^J$ could be made equal, meaning thereby that the wage rates in all regions is equal, but may be different from W_b^L. The labor has no incentive to move from one region to another. This is consistent with the optimal allocation of labor between regions.

(b) $$C_t^L = \dot{W}_b^J - \dot{W}_b^L - T_b^{L\to J}$$

The transfer activity will be active in this case if C_t^L is positive. It means wage rate in Region J is higher than in Region L by more than the transport cost of labor.

If $\dot{W}_b^J - \dot{W}_b^L - T_b^{L\to J}$ is zero or negative the labor won't move from L to J.

$$\dot{W}_b^J - \dot{W}_b^L - T_b^{L\to J} = C \quad ,$$

C is a positive constant, then

$$W_b^L - W_b^J = C \quad , \quad W_b^L = C + W_b^J$$

Higher the value of C, meaning thereby larger differences in actual wages exist between two regions, greater differences in marginal productivities of labor in two regions would persist. A further examination of the above relation shows that whereas the wage rate is higher in Region J, the region of destination, the marginal productivity would be higher in Region L, the region of source. This will induce in the system malallocation of labor between regions.

(c) $$C_t = \dot{W}_b^J - \dot{W}_b^L \quad , \quad T_b^{L\to J} = 0 \quad ,$$

a free transport service for transferring labor. Then,

$$W_b^L - W_b^J = {}'W_b^J - {}'W_b^L$$

Marginal productivity of labor won't be equal in a pair of regions (in all regions), unless wage rates correspond to marginal productivities of labor in all regions. If wages do not correspond to marginal productivities, a free transport service would allow to persist misallocation of a resource. The marginal productivity is higher in Region L than in Region J, while the wage rate is higher in Region J as compared to the one in Region L, a similar result as in c.

Subsidy Prices and Rents to Scarce Resources

Subsidy prices pertain to commodities for which the availability constraints have been effective in the final (unique) solution of the problem. As indicated earlier it has lead to lower the value of the objective function of the direct problem by creating a semi-efficient situation. The value of the objective function of the dual has been reduced to the same amount. Thus, returns to resource owners, on the whole, have been decreased.

The subsidy prices indicate the amounts by which prices of the respective commodities may be raised so as to make the producers of those commodities raise production to the level of meeting their minimum levels specified in different regions. There could be different ways of handling these subsidy prices. Those subsidies could be paid direct to the consumers or producers. As indicated earlier, those subsidies are imputed back to resource owners as an increase in the returns to their resources employed for producing the commodities under reference. But it may be remembered that overall returns to resources have decreased. The comparison of the results of two solutions of the problem with and without availability constraints, will indicate as to which category of resource owners in different regions has gained on account of the availability constraints; and which category of resource owners has incurred losses. It is now a welfare economics field, which on the basis of compensation criteria may lead to the decision of taxing away from resource owners who have gained due to this, an equivalent amount to the subsidies to be paid. It may be noted that overall loss is still there in the system, the effects of which may be different in different regions and on different classes of farmers and resource owners. Welfare considerations may also lead us to know how to smooth out these impacts.

The subsidy prices give us the amounts by which the actual specified prices, in our problem in the beginning, could be adjusted. If the model is run with these adjusted prices, we would be sure that in each region supplies of each final product, for which availability constraints were put earlier, are at least equal to desired levels. Now, there is no need of separately including the availability constraints. The adjusted finished product prices are, therefore, a meaningful and consistent set of prices for an inter-regional system.

It bears mention here that with this adjustment in prices, we have lost track of demand side to some extent. If the adjustment in prices is small, still the amount supplied may be demanded at adjusted prices in different regions. But in case the adjustments are of higher magnitudes, the amounts supplied may not be demanded at the adjusted prices. It may, then, result in an excess supply of commodities under reference. These excess quantities might be absorbed by lowering the respective prices by appropriate quantities in some other regions with comparatively higher prices.

There is a way to handle the problem within the model. A commodity for which availability constraint is binding, and it requires adjustment in price for making the system free of this constraint, a step demand function can be included in the model to take into account excess supply at the adjusted price. Similarly, for a commodity for which it has been found in the solution that there is an excess supply in a region at the preassigned level of the price or it is expected that an excess supply can occur, the step demand function can be incorporated for it.

The method used for incorporating a step demand function is in essence the same as employed by Yaron and Heady (1961) for solving non-linear programming problems with a separable objective function. Two modifications in the above method are made to convert the monopolistic solution for commodities with demand functions in the program to a free competition solution.

To make the exposition somewhat easier, we may examine a case of an immobile final product being produced by a single production activity as the only output.

The net income of the activity in this case in Region L is C_f^L.

$$C_j^L = a_{fj}^L P_f^L - V_j^L$$

Let the activity level be such that $a_{fj} = 1$ unit of a final product. Then

$$C_j^L = P_f^L - V_j^L \quad , \quad P_f^L = C_j^L + V_j^L$$

C_j^L for the activity at the positive level in the optimal program equals the real cost (imputed value of scarce resources employed), Z_f^L.

C_j^L of the commodity is a continuously decreasing function in X_j^L (level of activity - the amount produced as $a_{fj}^L = 1$, assumed). In the case of demand function being linear, and with equal price intervals, the step wise function may look like:

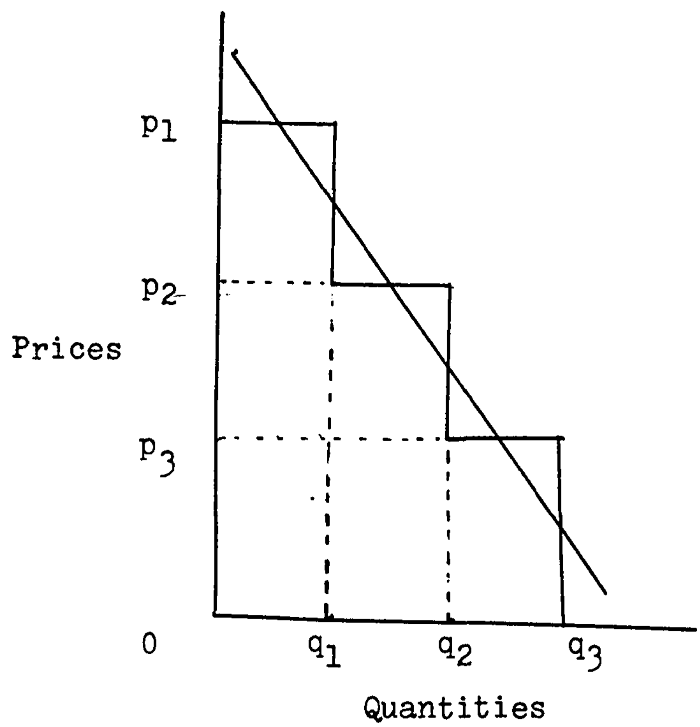

Fig. 1. Linear demand function

Here the area under the linear demand function up to a particular discrete price will be equal to the area under the continuous linear demand function. The demand functions with unequal price intervals and quadratic type one are approximated by the step function as in Fig. 2. It is bounded from outside by the corresponding continuously decreasing function in x_j^L.

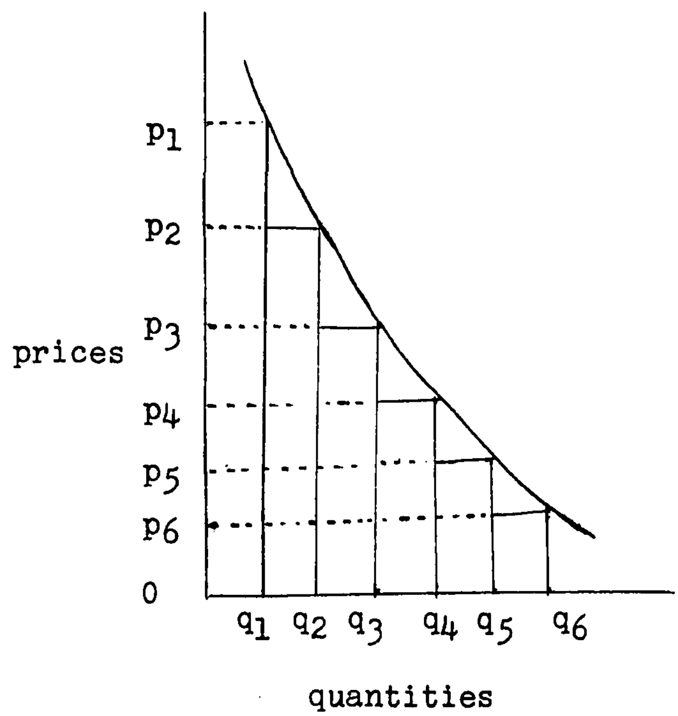

Fig. 2. Quadratic demand function

The j th activity may be subdivided into relevant number of sub-activities, corresponding to different steps, as

$$\ddot{J}_1^L,\ \ddot{J}_2^L,\ \ddot{J}_3^L,\ \dots,\ \ddot{J}_s^L\ .$$

The level of these sub-activities is indicated by

$$x^L_{j_1},\ x^L_{j_2},\ x^L_{j_3},\ \ldots\ ,\ x^L_{j_s}\ .$$

The corresponding prices and quantities for these sub-activities are

$$P^L_{f_1},\ P^L_{f_2},\ P^L_{f_3},\ P^L_{f_4},\ \ldots\ ,\ P^L_{f_s}\quad \text{and}$$

$$q^L_{f_1},\ q^L_{f_2},\ q^L_{f_3},\ q^L_{f_4},\ \ldots\ ,\ q^L_{f_s}\quad \text{, respectively.}$$

The net income per unit of the sub-activities now can be written as

$$\begin{aligned} C^L_{j_1} &= P^L_{f_1} - V^L_j \\ C^L_{j_2} &= P^L_{f_2} - V^L_j \\ &\vdots \\ C^L_{j_s} &= P^L_{f_s} - V^L_j \end{aligned} \tag{5.27}$$

V^L_j is assumed as constant.

For each sub-activity of the j th activity, a corresponding constraint is to be added to the constraints of the system. These constraints for sub-activities will read as, (a^L_{fj} assumed equal to 1)

$$
\begin{aligned}
X^L_{j_1} &\leq q^L_{f_1} \\
X^L_{j_2} &\leq (q^L_{f_2} - q^L_{f_1}) \\
X^L_{j_3} &\leq (q^L_{f_3} - q^L_{f_2}) \qquad (5.28) \\
X^L_{j_4} &\leq (q^L_{f_4} - q^L_{f_3}) \\
&\vdots \\
X^L_{j_s} &\leq (q^L_{f_s} - q^L_{f_{(s-1)}})
\end{aligned}
$$

The net income per unit level of the commodity will be decreasing. So the j^L_1 will be dominating j^L_2, and j^L_2 will be dominating j^L_3 and so on. The objective function of the program will accordingly change so as to include sub-activities in place of the main activity in a particular region.

We may illustrate the case of a mobile product now.

In the mobile product two types of activities are involved, production and transfer activities. Let us suppose a final product, f, is being transferred from Region 1 to Region 2 and it is produced in both the regions in the final solution. There may be an excess supply of a good in Region 2 due to the higher price fixed there at the beginning. The demand in a region for the commodity is being met through the production activity as well as the transfer activity. It is, therefore, necessary that the P_f^2 may be adjusted in the sub-activities for the production and the transfer activities for Region 2. The sub-activities for production will be j_1^2, j_2^2, j_3^2, ..., j_s^2 and for transfer $t_1^{1\to 2}$, $t_2^{1\to 2}$, $t_3^{1\to 2}$, ..., $t_s^{1\to 2}$. The $p_{f_1}^2$ will correspond to j_1^2 and $t_1^{1\to 2}$; $p_{f_2}^2$ to j_2^2 and $t_2^{1\to 2}$ and so on. The constraint will be somewhat different than before, as, (a_{fj}^2 and $a_{ft}^{1\to 2}$ taken as equal to 1 unit of a final product)

$$X_{j_1}^2 + X_{t_1}^2 \leq q_{f_1}^2$$

$$X_{j_2}^2 + X_{t_2}^2 \leq (q_{f_2}^2 - q_{f_1}^2)$$

(5.29)

$$X_{j_3}^2 + X_{t_3}^2 \leq (q_{f_3}^2 - q_{f_2}^2)$$

$$\vdots$$

$$X^2_{j_s} + X^2_{t_s} \leq (q^2_{f_s} - q^2_{f_{(s-1)}})$$

The objective function will be adjusted so as to replace the particular production activity and transfer activity by sub-activities in a particular region.

There is no difficulty in incorporating the demand relation for more than one final product; the final product may be produced by a single activity, by a single sub-activity within an activity or by many activities or in combination with intermediate products. The corresponding adjustments are to be made in the objective function and necessary constraints are to be added.

As mentioned earlier, two adjustments are made in the approach by Yaron and Heady (1961):

$$P^L_f = Z^L_j + V^L_j$$

$$P^L_j - V^L_j = Z^L_j \ , \quad C^L_j = Z^L_j$$

C^L_j is the average net revenue (income) and Z^L_j is the real cost (imputed cost to scarce resources).

The producers in the competitive industry will expand production until the equilibrium as stated above is reached. The approach of Yaron and Heady (1961) maximizes the marginal net revenue whereas here it is maximization of average net income. The former ends with monopolistic situation and the latter with the competitive market with no excessive profits.

Another adjustment is done after the solution. All sub-activities within a main activity use same technical coefficients, but net incomes are different. The final price of the product corresponds to that sub-activity which is the last one in the descending order of net income with a positive level in the optimal solution. The same product has been evaluated at higher prices than this price in the solution, for sub-activities having higher net income than the last one to enter. The additional value thus accrued in the solution has to be subtracted. The economic meaning of this correction is taking away of the consumers' surplus from the producers in the industry. In this case producers' surplus is zero, as constant costs of production are assumed. It is possible to incorporate increasing costs within the model as well. It can be shown that even after this correction the solution is optimum. The sub-activities enter in order of their net income in the solution.

Scarce immobile resources will be earning rents (imputed returns or prices). This rent is a scarcity rent determined by the system. For example, land in general or if there are different categories of land, each category, if it is scarce (all used up) in the final (unique) solution of the dual in a region, will be earning a rent. If a resource is not scarce in a region it will have a zero rent. The rent for a particular resource, say, land or a special category of land, can be compared between different regions. The minimum rent could be zero if the resource is not scarce in any one of the regions; it will be positive if it is scarce in all regions. The differential rents for different regions for a resource can be shown by:

$$\begin{array}{c}\text{actual rent}\\\text{in a region}\end{array} - \begin{array}{c}\text{minimum rent}\\\text{among all regions}\end{array} = \begin{array}{c}\text{differential rent}\\\text{for a region}\end{array} .$$

In the classical theory differential rent arises because different qualities of land are used to produce a certain product which carries a single price in the competitive market. The lowest quality of land will earn zero rent, while better quality of land will receive (differential) rent, depending on the difference in the output of the same output with same quality and quantity of other inputs on two lands.

Several authors have suggested that the quality of land in the classical theory, if allowed to include locational advantages, the differential rents can be more generally discussed in the classical theory framework. The model yields results in respect to rents which correspond to the more general interpretation of the classical theory, with one more adjustment that there are more than one market now.

It may be of interest to note that subsidy prices $\bar{P}_f^L$ seem to achieve the equality of supply and demand by affecting the behavior of suppliers of final commodities, whereas rents attempt to attain the equality of supply and demand by influencing the behavior of demanders.

Accounting Prices

The marginal value productivities of resources, yielded by the model with and/or without availability constraints, can be compared with the actual prices prevailing for those resources in different regions, as, for example, prevailing land rents, wages, commodity prices, interest, et cetera. The former sets yielded by the model are generally termed accounting prices. The r, correlation coefficient between the accounting prices and the prevailing prices for each resource in different regions, will give an idea how these two series are close together. A high correlation (and r^2) would suggest that the factor under discussion is quite close to the optimal allocation. A low correlation for a resource between two series would indicate that the allocation of the factor between regions and activities is far from optimum and/or the model objective function and restrictions are not quite in line with reality. It would require either reformulation of the problem or policy measures to bring the economy on right path of development. It may need both these adjustments. This analysis would thus help in diagnosis of the structural disequilibrium in the utilization of resources in the economy with known coefficients and the given set of product prices in different regions and the pattern of demand.

The accounting prices are very relevant for investment allocation and planning in cases where the actual prices of resources differ widely from the ones given by the model. The best allocation of investment on different prospects certainly would be that which is according to the marginal value productivities of resources in different uses in different regions.

Inter-regional Equilibrium Characteristics of the Model

It may be desirable to state, in brief, how far the model meets the conditions of the inter-regional general equilibrium.

1. Prices of final products are given in the system. Com-

petitive prices of resources and of intermediate products are determined in the model. In the case of 'general equilibrium' in the sense of Walras (1954), the competitive prices of final products are also unknown.

2. The model covers only a part of the economy covering about 50 per cent of the national income. It is, therefore, partial in this respect. If the model is run for the whole economy, its conclusions will hold good.

3. Net income per unit of a production activity (including subsidy payments if any) in a region is equal to costs imputed to scarce resources and intermediates employed per unit of an activity. Net income is positive in the case of a final product. It is zero for an intermediate product by definition.

   Imputed price of an intermediate product in a region is equal to imputed returns to scarce resources and other intermediates engaged per unit of an intermediate product. Actual price of an intermediate would be equal to imputed price plus variable cost.

4. Adjusted per unit income ($C_f^L + \bar{P}_f^L$) of a mobile final product in Region L, the region of origin, would be less than the adjusted per unit income ($C_f^J + \bar{P}_f^J$) in the region of destination by $T_f^{L \to J}$, the variable transport cost from Region L to Region J, plus $a_t^{L \to J}\ \bar{P}_t$, the imputed value of

the transfer activity units used in transfering per unit of the final product from L to J. It will be true for commodity for which availability constraint is at least effective in one region, in a pair of regions. If transport is not restrictive, the absolute difference in net incomes for a final product between two regions would differ by the absolute value $|T_f^{L\to J}|$. If the further assumption is made that variable cost for a final product in two regions are equal, the adjusted price of a commodity in the above-mentioned case in a pair of regions would differ by the transport cost $T_f^{L\to J}$.

5. Absolute difference in the imputed price of a mobile intermediate product in a pair of regions, $|\bar{P}_i^J - \bar{P}_i^L|$, would be equal to $T_i^{L\to J}$, the transport cost of the intermediate product from one region to another, if the transport is not restricted. In case, transport is an effective restriction, then the difference would be increased by $a_t^{L\to J}\,\bar{P}_t$, ($a_t^{L\to J}$ is the transport unit employed in transfering a unit of an intermediate from Region L to Region J.)

6. Absolute difference $|W_b^J - W_b^L|$ in the marginal productivity of a mobile resource in a pair of regions would be equal to $|T_b^{L\to J}|$, in case transport is not limited. As discussed above for mobile final products and intermediates, this difference in the marginal productivity would further be

increased by $a_t^{L\rightarrow J}\ \overline{P}_t$ ($a_t^{L\rightarrow J}$ is the unit of transport activity used in transfering a mobile resource from Region L to J).

7. Absolute difference in the net incomes (so is the difference in prices) of a final product in a pair of regions for which either the availability constraint is not stated in both, or if stated but is not effective in either region, can be greater than the transport cost $T_f^{L\rightarrow J}$ plus $a_t^{L\rightarrow J}\ \overline{P}_t$ (defined earlier). This is due to specified prices of final products in different regions in the beginning.

8. It indicates the amount by which regional specified price of a commodity should be adjusted, for those commodities for which availability constraints are effective in a region, in order to insure the minimum amounts of those commodities available in a region. The adjusted price would be, then, in line with the price of a commodity in other regions. These adjusted prices are thus competitive prices.

The availability constraints in different regions and the corresponding prices are based on the quantities purchased at different prices over a recent period or on cross-sectional family budget data. The weakness of the model is that in case the price of a commodity is adjusted in a region the same quantity specified may not be demanded, unless the demand function is shifted to the right by the appropriate distance at the point of specified quantity for availability constraint. The excess supply in a region could be made to be absorbed by lowering correspondingly the price of a commodity by an appropriate value, in some other region. Another way to overcome this defect is to include in the model step demand functions for the commodities under reference.

Judged from the inter-regional general equilibrium standard, the model has one main weakness; that is, the prices of some of the final commodities could differ by more than the transport cost between two regions. This drawback could be remedied largely in specifying correctly availability constraints and prices of final products in the beginning.

It may be remembered that it is not a complete dynamic general equilibrium system. But taking the market prices as given, and making adjustments in consumption, income, and resource supply outside the model, it meets fairly the other characteristics of the one point equilibrium system. Including the above variables in the model would involve choice variables from both direct and dual problems appearing in the constraints of these problems. There is yet no way to construct workable linear programming in cases where choice variables from direct and dual problems appear in the constraints of one of these problems.

Model in the Matrix Notation

To close up the chapter it may be useful to represent the model in matrix notation. As an example, the vectors and technical coefficients matrices are shown for Region L in Table 13.

$$X^L = \begin{bmatrix} X_j^L \\ X_t^L \\ X_t^J \end{bmatrix}$$

a column vector of activities of Region L; its order is p + g + (u - 1) g .

P is the number of production and dummy activities and g, the number of transport activities in a region. u is the number of regions.

X_j^L elements of the vector is p, representing level of production and dummy activities in Region L. Similarly, X_t^L contains g elements of the above vector. These represent level of export activities of different commodities from a region. X_t^J elements require some explanation. These pertain to imports from Region J to L ($J \neq L$). Export activities have been taken into account as X_t^L. Unless a commodity is shown as imports in a particular region, it can't be used there. X_t^J are thus import levels corresponding to export

Table 13. Relation of the model in matrix form

R^L / C'^L	$C^L_j =$	$C^L_t =$	$C^J_t =$
(Net income)	$C^L_{j_1}$ $C^L_{j_2}$ ... $C^L_{j_p}$	$C^L_{t_1}$ $C^L_{t_2}$ ... $C^L_{t_g}$	0 0 0 0 0
Level of resources, inter-mediates, final products	Production and dummy activities	Transport activities relating to exports from L to J	Transport activities relating to imports from J to L
	J^L_1 J^L_2 ... J^L_p	t^L_1 t^L_2 ... t^L_g	t^J_1 t^J_2 ... $t^J_{(u-1)}$
$R^L_b = \begin{bmatrix} R^L_{b_1} \\ R_{b_2} \\ \vdots \\ R_{b_m} \end{bmatrix}$	$A^L_{b_1}$	$A^L_{b_2}$	$A^L_{b_3}$
$R^L_i = \begin{bmatrix} R_{i_1} \\ R_{i_2} \\ \vdots \\ R_{i_n} \end{bmatrix}$	$A^L_{i_1}$	$A^L_{i_2}$	$A^L_{i_3}$

Table 13. (Continued)

R^L/C'^L	$C^L_j =$	$C^L_t =$	$C^J_t =$
(Net income)	$C^L_{j_1}\ C^L_{j_2}\ \dots\ C^L_{j_p}$	$C^L_{t_1}\ C^L_{t_2}\ \dots\ C^L_{t_g}$	0 0 0 0 0
Level of resources, intermediates, final products	Production and dummy activities	Transport activities relating to exports from L to J	Transport activities relating to imports from J to L
	$J^L_1\ J^L_2\ \dots\ J^L_p$	$t^L_1\ t^L_2\ \dots\ t^L_g$	$t^J_1\ t^J_2\ \dots\ t^J_{(u-1)}$
$R^L_f = \begin{bmatrix} R_{f_1} \\ R_{f_2} \\ \vdots \\ R_{f_o} \end{bmatrix}$	$A^L_{f_1}$	$A^L_{f_2}$	$A^L_{f_3}$
$R_t = R_t$	$A^L_{t_1}$	$A^L_{t_2}$	$A^L_{t_3}$
	0 0 0 0 0		0 0 0 0 0

Table 13. (Continued)

X^L = Level of activities	$\bar{P}^L$ = Accounting prices
$X_j^L = \begin{bmatrix} X_{j_1}^L \\ X_{j_2}^L \\ \vdots \\ X_{j_p}^L \end{bmatrix}$	$W_b^L = \begin{bmatrix} W_{b_1}^L \\ W_{b_2}^L \\ \vdots \\ W_{b_m}^L \end{bmatrix}$
$X_t^L = \begin{bmatrix} X_{t_1}^L \\ X_{t_2}^L \\ \vdots \\ X_{t_g}^L \end{bmatrix}$	$\bar{P}_i^L = \begin{bmatrix} \bar{P}_{i_1}^L \\ \bar{P}_{i_2}^L \\ \vdots \\ \bar{P}_{i_n}^L \end{bmatrix}$
$X_t^J = \begin{bmatrix} X_{t_1}^J \\ X_{t_2}^J \\ \vdots \\ X_{t_{(u-1)g}}^L \end{bmatrix}$	$\bar{P}_{f_t} = \begin{bmatrix} \bar{P}_{f_1} \\ \bar{P}_{f_2} \\ \vdots \\ \bar{P}_{f_o} \end{bmatrix}$ $\bar{P}_t = \bar{P}_t$

level activities of different region to a particular region L.

In the system there will be u vectors like X^L, one for each region.

$$C^L = \begin{bmatrix} C_j^L \\ C_t^L \\ C_t^J \end{bmatrix}$$

a column vector of order $p + g + (u - 1)g$, indicating the net income per unit of activities

C_j^L contains p elements corresponding to X_j^L, C_t^L is comprised of g elements refering to X_t^L, and C_t^J are all zero. The reason for these being zero is that these pertain to $(u - 1)g$ import activities the net income for which has been taken into account already in export activities, C_t^L. It does not make any difference whether it is accounted for in export or import activities. When it is included for export activities, it is assumed that the responsibility for the export lies with the exporting region.

$$A^L = \begin{bmatrix} A_b^L \\ A_i^L \\ A_f^L \end{bmatrix}$$

a technical coefficient of $(m + n + o) \times [p + g + (u - 1)g]$ order for a Region L

A_b^L is the part of matrix of technical coefficients for resources, the quantity of a resource required per unit of an activity in Region L. Its order is m x [p + g + (u - 1)g]. Coefficients pertaining to inputs and exports are positive and to imports are negative. Under the transfer activities each coefficient contains two sub-coefficients, one pertaining to local inputs and the other to exports or imports. These two sub-coefficients are combined into one for the convenience of presentation.

A_i^L is a part of matrix of technical coefficients for intermediate products in Region L. The order is n x [p + g + (u - 1)g]. The coefficients referring to production and imports are shown as negative and to inputs and exports as positive. Here, also, for transfer activities referring to exports and imports, each coefficient is composed of two such coefficients, one pertaining to local inputs and the other to quantities exported or imported.

A_f^L is the portion of the matrix showing technical coefficients for final products. Its order is o x [p + g + (u - 1)g]. It takes into account the amount of a final product produced per unit of production and dummy activities and that transferred by a unit of transfer activities. Production and imports are negative and exports are positive. It has been done to change the inequality sign for the constraint referring to final products from greater than to less than.

The coefficient matrix is further subdivided as A_b into $A^L_{b_1}$, $A^L_{b_2}$ and $A^L_{b_3}$, A_i into $A^L_{i_1}$, $A^L_{i_2}$ and $A^L_{i_3}$, and A_f into $A^L_{f_1}$, $A^L_{f_2}$ and $A^L_{f_3}$. The division is shown in Table 13.

A^L_t is a row vector indicating the transport units used per unit of different transfer activities in a region. Its order is [(p + g + u(g - 1)]. All other elements would be zero except ug, for export activities.

$$R^L = \begin{bmatrix} R^L_b \\ R^L_i \\ R^L_f \end{bmatrix}$$

A column vector of limiting constraints for Region L. Its order is (m + n + o).

R^L_b is a portion of elements numbering m referring to supply of different resources. R^L_i have the elements numbering n, all equal zero, pertaining to initial supply of intermediate products. R^L_f is comprised of o elements. It has a negative sign. It is the minimum amounts of a finished product required in a region. The final products which are free from such availability constraint have R^L_f equal to zero.

R_t is a constant showing the total units of transport available.

$$\bar{P}^L = \begin{bmatrix} W_b^L \\ \bar{P}_i^L \\ \bar{P}_f^L \end{bmatrix}$$ a (m + n + o) order column vector of imputed prices of resources

W_b^L indicates m elements, imputed prices of resources, $\bar{P}_i^L$ shows n elements, imputed prices of intermediates, and $\bar{P}_f^L$ represents 0 elements, subsidy prices of final products. In the case of final products, the elements $\bar{P}_f^L$ will be non-zero for binding constraint for availability of a final product in a region, otherwise these will be zero (for non-binding constraints and for those final products for which no constraint has been put).

$\bar{P}_t$ is the imputed price for transport activity. It can be interpreted in the form of a vector of order p + g + g(u - 1) having all its elements as equal. This vector is same for all regions, so it does not contain any superscript.

The matrices and vectors explained above refer to a region. Such matrices and vectors will be these for each region in the model.

The direct problem and the dual of the model can be stated in a familiar matrix notation:

<u>Primal</u>

$$(5.30) \quad \text{Max } f(Z) = C'^1X^1 + C'^2X^2 \dots + C'^uX^u$$

subject to

(5.31) $A^L X^L \leq R^L$

$$A_t^1 X_t^1 + A_t^2 X_t^2 \ldots + A_t^u X_t^u \leq R_t$$

$$X^L \geq 0$$

<u>Dual</u>

(5.32) $\text{Min } F(w) = R'^1 \overline{P}^1 + R'^2 \overline{P}^2 \ldots + R'^u \overline{P}^u + R_t \overline{P}_t$

subject to

<u>Production activities</u>

$$A'^L_{b_1} w^L_b + A'^L_{i_1} \overline{P}^L_i + A'^L_{f_1} \overline{P}^L_f \geq C^L_j$$

<u>Transport activities</u>

(5.33)

$$A'^L_{b_2} w^L_b + A'^L_{i_2} \overline{P}^L_i + A'^L_{f_2} \overline{P}^L_f + A'^J_{b_2} w^J_b + A'^J_{i_2} \overline{P}^J_i + A'^J_{f_2} \overline{P}^J_f$$

$$+ \; A'^{L}_{t} \; \bar{P}_{t} \;\; \geq \;\; C^{L}_{t}$$

$$\bar{P}^{L} \; , \; \bar{P}_{t} \;\; \geq \;\; 0$$

The restriction for transport activities involves coefficients for the region of source and region of destination.

VI. OPERATIONAL MODELS AND INVESTMENT ALLOCATION

An inter-regional programming model developed in Chapter V may require adjustments in many respects, depending on availability of data, differences in agro-economic conditions between regions, extent to which objectives could be met due to institutional and social restrictions not accounted for in the model, et cetera. The purpose of this chapter is to state specific operational models within the framework of the general model referred to above.

The number and kind of activities, types of resources available, and so forth, were assumed same in all regions in the general model. Actually, this will not be true in most cases. Activities, particularly, may differ between regions. For notational convenience the above-mentioned assumption may, however, be retained in this chapter. The notations, as used in the general model, are kept in the presentation of this chapter unless otherwise stated.

Operational Models

Model A

The third five-year plan (Government of India, 1961) gives the values of instruments to be used during the planning period in respect to irrigation, soil conservation and land reclamation, chemical fertilizers, organic manures, plant protection, improved seeds, community development and cooperation, and implements. The resources available at the end of the third five year plan can be estimated by adding the values of above-mentioned instruments to the corresponding value of resources available at the end of the second five year plan.

The objective function of the model is the same as 5.6.

$$(6.1) \quad \text{Max: } \sum_{L=1}^{u} \sum_{j=1}^{p} C_j^L X_j^L + \sum_{L=1}^{u} \sum_{t=1}^{g} C_t^{L\rightarrow J} X_t^L$$

The restrictions of the model are made specific, which are as follows:

1. Land area region-wise:

	Type	Level
a.	Irrigated	I_a^L
b.	Unirrigated	U_a^L

This restriction includes as well new land to be brought under cultivation through land reclamation. The above division of land takes into account the extension in facilities of a very important resource, i.e., irrigation. Some crop rotation activities may be possible on irrigated lands and not on unirrigated land. Similarly, some crop rotations may be relevant for unirrigated lands; due to their low net income are not grown on irrigated land. In case a crop rotation can be adopted both on irrigated and unirrigated lands, it is represented by two separate activities, one for irrigated and another for unirrigated lands.

With the availability of information from soil surveys being carried out in the country, it will be possible to divide the land into soil types differing in productivity and suitability for various crops. The land restrictions will then correspondingly change and adjustment in specifying activities will be required.

2. Chemical fertilizer availability at certain locations:

	Type	Level
a.	Nitrogen	N^L
b.	Phosphatic	$P_2O_5{}^L$
c.	Potassic	K_2O^L

The resource is mobile; L represents the region (location) of production or import of the resource. Availability of the fertilizer at the national level can easily be broken down by locations. It will take into account the transport costs in the allocation of the resource.

These fertilizers won't be used on all the available land. Mostly these will be relevant inputs for irrigated areas and areas with some minimum level of assured rainfall. The activities competing for fertilizers will be divided into two: (a) those to be raised with fertilizer, and (b) those that could be raised without fertilizers. Thus same crop rotation will have two activities: with fertilizers and without fertilizers. An activity with fertilizers can be further subdivided, as is generally called into processes, to take into account the levels and combinations of fertilizers.

Fertilizer trials (Government of India, 1959) on cultivators' fields and experiments conducted on research stations have already yielded important information on input-output coefficients for fertilizers. The facilities for collecting more information in this respect are being extended in the third five year plan.

3. Organic manures in different regions

Type	Level
a. Urban compost	C_u^L
b. Rural compost	C_r^L
c. Green manuring	G_m^L

The resource is mostly immobile and could mostly be used in the region. The information on input-output coefficients for this resource may not be very precise, but fairly good regional estimates of these are available. The recommendations of agricultural departments for different regions are based on these estimates. The information in this respect is being improved upon through various schemes in the third plan.

4. Insecticides availability at certain locations

Different types of insecticides would be made available through production in the country and imports. Unfortunately, the coefficients in this respect are very rough. The restriction is indicated by I_n^L.

Apart from the above mentioned resources, the improved seed production and distribution, adoption of improved technology through extension service and community development programs, use of improved implements, et cetera, will have impact on production. Their effect and of some other qualitative measures, can be included in the model through adjusting relevant output coefficients of different activities.

It may not be necessary to include human and Bullock labor as restrictions in the model. Farm management investigations (Government of India, 1957) and other similar surveys have shown that human and Bullock labor is grossly underemployed in various regions under the existing land use pattern.

Feasibility of the final solution can be tested for human and Bullock labor, if necessary, in some regions afterwards. In cases where such land use pattern is not feasible in a particular region, the relevant restriction could be incorporated. If human and Bullock labor is not a part of restrictions of the system, the cost on these resources for different activities is to be included in the variable cost. The data on wages of human labor are available for different regions and Bullock labor cost may be based on cost of maintenance of Bullock studies conducted in the country and some other indirect estimates.

Besides these restrictions, the operational model will have restrictions of intermediate products, final products and transport, of the type 5.8, 5.9, 5.10, and 5.11 specified for the general model in Chapter V. It may be noted that capital, as such, has not been included in the system of restrictions. It has been included indirectly through capital represented by irrigation, land reclamation, fertilizers, et cetera. A specific model for investment allocation is developed in this chapter later.

This type of model will give optimal allocation of resources and optimal land utilization pattern. This land utilization pattern may not be possible to attain in the five years, relevant for the plan period, due to institutional and social factors. Thus, the optimal land utilization pattern will need further adjustments. The estimates outside this model have to be worked out for the magnitude of changes possible in different regions through extension, community development, et cetera towards the directions leading to the optimal land utilization pattern. Once such estimates are available, these could be included in the system of restrictions. The implications of these restrictions are explained in Model D. The optimal solution, including the impact of these restrictions, will be the relevant attainable value of the program in five years.

Model B

This model differs from A only in the scope of coverage. There is very meager information available for livestock production needed for Model A. Crop production forms the major part of the income from agriculture sector, as about 90 per cent. Among crops, nine food crops, five oil seeds, sugarcane, jute and cotton cover about 80 per cent of the total cropped area in the country. The remaining 20 per cent area is covered by minor crops and fodder crops. Fodder crops account for a major slice of this 20 per cent cropped area of the country. The livestock activities and their major input fodder crops could be excluded from the program. This adjustment will reduce largely the number of restrictions of intermediate products of the system. All the other conditions remain the same as in Model A.

Model C

The restrictions specified for the change in the land use pattern as mentioned in Model A for five year period in different regions may not be very wide. In some crops, it may be 10 per cent or more change in acreage, while in other crops, it may be even 5 per cent or less change in area. If such magnitude of changes in areas of different crops allowed in different regions are not very wide, most of the food production in the region will be consumed there itself. It may not thus be necessary to include transfer activities in the model. Model C is thus same as Model B, with transfer activities either all eliminated or only a few relevant transfer activities kept in the model. The availability constraint of agricultural products mostly will be at the national level in the model.

The objective function then is

$$(6.2) \qquad \text{Max:} \sum_{L=1}^{u} \sum_{J=1}^{p} C_j^L X_j^L$$

Restriction 5.10 for transport is dropped and other restrictions of Models A and B are adjusted to exclude transfer activities.

Model D

So far in Models A, B and C, the crop production activities have been represented by crop rotations. It will be easy to find relevant coefficients for a crop, rather than coefficients for that crop grown under different rotations. Of course, the coefficients in the latter case will be more precise for the model. A workable adjustment is made in this model as compared to Model C by replacing the crop rotation activity by an activity represented by each crop, say, wheat, rice, cotton, et cetera. Assume that per unit of an activity is equal to an acre under the crop. The restrictions for change in the area under each crop, as mentioned earlier, will then be:

$$(6.3) \qquad - X_j^L \leq - A_{j(min)}^L$$

$$X_j^L \leq A_{j(max)}^L$$

X_j^L, the area under a particular crop, can be adjusted during the five years within the limits that

$$A^L_{j(max)} \geq X^L_j \geq A^L_{j(min)} ,$$

$A^L_{j(max)}$ is the maximum area that could be brought under the crop and $A^L_{j(min)}$ the acreage to which the area under the crop could be reduced.

The system will have an overall restriction for each land category of type 5.7, that the total land category required by all crop activities in a region does not exceed its supply in that region. These maximum and minimum limits on acreage can be prescribed such that resulting cropping pattern is possible.

The two additional constraints on acreage for a particular crop yield on important information on the rent for that crop in the region.

The relations in respect to rent are summarized as follows.

Let Y^L indicate general rent of land class for Region L.

$$Y^L = 0 \text{ if } \sum_j X^L_j < R^L_b ,$$

R_b^L is the total land class available for crops in Region L.

$$\gamma^L > 0 \text{ if } \sum_j X_j^L = R_b^L .$$

Let $\gamma^L_{j(max)}$ and $\gamma^L_{j(min)}$, the corresponding rents for $A^L_{j(max)}$ and $A^L_{j(min)}$ acreage limits

$$\gamma^L_{j(max)} = 0 \text{ if } X_j^L < A^L_{j(max)}$$

$$\gamma^L_{j(max)} > 0 \text{ if } X_j^L = A^L_{j(max)}$$

(6.4)

$$\gamma^L_{j(min)} = 0 \text{ if} - X_j^L < - A^L_{j(min)}$$

$$\gamma^L_{j(min)} > 0 \text{ if} - X_j^L = - A^L_{j(min)}$$

Rent for a specific crop is:

(6.5) $r^L + r^L_{j(max)} - \gamma^L_{j(min)}$

As may be seen from the above relations, if

$$A^L_{j(min)} < X^L_j < A^L_{j(max)} \quad ,$$

the second and third terms in 6.5 are zero. The specific rent for a crop is equal to general rent r^L, which may be equal to or greater than zero.

But maximum and minimum area limits can't be binding at the same time. Therefore, in the case of a binding acreage restraint, either $r^L_{j(max)}$ is equal to zero or $r^L_{j(min)}$ is equal to zero. If the maximum limit is binding, the general rent r^L, indirectly the cost of the commodity, is increased by $r^L_{j(max)}$ to reach the equilibrium condition. On the other hand, if the minimum area limit is effective, the r^L has to be lowered by $r^L_{j(min)}$ to attain the equilibrium condition. The result may be that $r^L - r^L_{j(min)}$ is a negative quantity, meaning that there is negative rent for a specific crop. The conclusion seems to be somewhat startling at sight. It could be interpreted in another way.

In order that the commodity can enter at the optimal solution at the $A^L_{j(min)}$ level, its income may be adjusted by addition of the absolute value equivalent to the negative rent.

The other restrictions will be the same as Model C, namely availability constraints, and resource restraints, and some restrictions, if necessary, pertaining to intermediate products.

Model E

It is a further simplified form of Model D. In this case, all other resource restrictions are dropped except for regional land restrictions and the maximum and minimum area limits as used in Model D. The availability restrictions of final products at the national level are retained for products for which targets of production are specified in the five year plans. If needed there will be a few restrictions of intermediate products (may not be any) in different regions, as fodder area and livestock production are not included in it.

It will be very easy to operate this model and it will yield very useful results from practical point of view for five year plans. It may be operated even for each year of the five year plans with specifying regional area restrictions and national availability constraint of final products for the relevant periods.

A serious criticism against this model could be that important inputs, such as fertilizers and insecticides, have not been taken into account. Irrigation has been accounted for by dividing the land into irrigated and unirrigated lands. It bears mention here that though the fertilizers and insecticides are very important for increasing production, their contribution to the total production is not very great at present. Only a small proportion of cropped area is fertilized and protected against plant pests and diseases. This model will give the optimal land use pattern without giving the allocation of fertilizers, insecticides, et cetera. It is very easy to find the coefficients for this model from area and yield statistics published by Directorate of Economics and Statistics, Ministry of Food and Agriculture, Government of India.

The optimal allocation of any resource such as fertilizers, insecticides, can be superimposed on a given land use pattern, through the model discussed next.

Model F

This model deals with an optimal allocation of a single resource given the land use pattern of different regions. The problem can be formulated either as a maximization one or minimization one; the results will be the same. One is the dual of the other. The model is represented so as to find out allocation of fertilizers between regions and between crops within regions.

$$(6.6) \quad \text{Max:} \sum_{L=1}^{u} \sum_{j=1}^{p} \sum_{i=1}^{n} C_{ij}^{L} X_{ij}^{L}$$

subject to

(6.7) $\sum_{L=1}^{u} \sum_{j=1}^{p} \sum_{i=1}^{n} a_{bij}^{L} X_{ij}^{L} \leq R_b$, b(1, 2, 3) ,

(6.8) $\sum_{i=1}^{n} X_{ij}^{L} \leq A_j^{L}$,

(6.9) $X_{ij}^{L} \geq 0$.

The production surface is assumed to be forming a convex set. There are p x n activities; an activity is an acre of j th crop with i th dose of a fertilizer or a particular combination of fertilizers. On the basis of response data, let us suppose coefficients for N 20 lbs, N 40 lbs, N 60 lbs per acre for a crop are available, then each dose of a fertilizer for a crop is a separate activity. Similarly, if different combinations of nitrogen, phosphorous and potash are relevant for a crop, each combination, in itself, is an activity. These doses of fertilizers may vary from one crop to another, but for notational convenience, these are taken as equal to n for each crop. It is assumed that there are p x n activities. C_{ij}^{L} is the net income per acre due to the fertilizer application for i th dose applied to j th crop in Region L. It is worked out by multiplying the additional production per acre due to fertilization with the market price of the produce and subtracting from it the cost involved in the application of fertilizers and other complementary inputs. The transport costs of fertilizers can be included in these costs.

R_b is the total amount of fertilizer b (b = 1, 2, 3 - N, P_2O_5, K_2O). The first restriction states that the total fertilizer b used by all activities does not exceed its supply, R_b.

A_j^L is the acreage fixed for Crop j in Region L which is eligible for fertilizer application. X_{ij}^L is the level of j th crop fertilized at the rate of i th dose. Constraint 6.8 thus reads that area required by all activities pertaining to Crop j does not exceed the area fixed for it in the region A_j^L for that crop.

The model maximizes returns from given quantities of fertilizers applied to the given land use pattern, and prices of commodities produced are known. Under these conditions, it yields the optimal allocation of fertilizers in different regions and by crops within regions. It is very easy to operate the model and it yields very useful information for distribution of fertilizers. It can be worked for each year land use pattern estimated in advance.

The dual of the model yields important information on the marginal productivity of different fertilizers. The objective is as follows.

$$(6.10) \quad \text{Minimize:} \quad \sum_{b=1}^{3} P_b \, R_b + \sum_{L=1}^{u} \sum_{j=1}^{p} \bar{P}_j^L \, A_j^L$$

subject to

$$(6.11) \quad \sum_{b=1}^{3} P_b \, A_{bij}^L + \bar{P}_j^L \geq C_{ij}^L$$

and

$$(6.12) \quad P_b \; \bar{P}_j^L \geq 0 \quad .$$

P_b is the accounting price for the b th fertilizer, and $\bar{P}_j^L$ is the additional value to be added per acre due to the land restriction to attain the equilibrium situation for j th activity in Region L. $\bar{P}_j^L$ will be zero for a crop for which

$$\sum_{i=1}^{n} X_{ij}^L < A_j^L \quad ,$$

and greater than zero when

$$\sum_{i=1}^{n} X_{ij}^L = A_j^L \quad .$$

It means due to limited supplies of fertilizers if all the crop acreage in a region could not be fertilized at the optimal solution, $\bar{P}_j^L$ will be zero. The accounting price of a fertilizer will be helpful in making decisions about its production and imports.

To close up this section, it may be noted that Models E and F are simple to operate but are expected to yield very useful results for policy making and policy execution. These two models may not give as efficient a solution as if it would have resulted in case land use pattern and fertilizer allocation have been determined simultaneously in one model.

Investment Allocation

Capital is one of the most crucial factors limiting the general rate of growth of development in the less developed countries. Capital allocation in the operational models has been attempted through the allocation of resources in which capital has already been invested, irrigation, fertilizers, insecticides, et cetera. An important problem facing those countries is how best to allocate the investment funds among different projects in order to meet to the maximum extent the goals of planning. A number of criteria are suggested for the purpose.

<u>Capital-output ratio</u>

The most commonly talked about criterion is capital-output ratio. It is expressed in different forms as capital-output ratio of the project, capital-value added ratio of the project, capital-output ratio of the project taking into account total capital used in producing the commodity by the project, including the capital used in producing all materials and services purchased, the latter portion of the capital is the backward effect of the project, and so forth. A further improvement is suggested to take into account in the capital-output ratio of the forward effects of the projects also in the economy, similar to those as of backward effects. The forward and backward effects are often called indirect effects. Apart from these indirect effects, there may be secondary effects through changes in income, employment, et cetera.

Buchanan (1945) was among the first to recommend the "minimum capital-output ratio" test for investment in under-developed countries. This test would be valid under the rather strict assumptions (a) capital is the only scarce factor in the economy. In an approximation, it can be said that capital is the scarcest factor, in relative terms. (b) If different products are required to be produced from the available capital, their market prices coincide with their social values. (c) Constant costs hold for production of these products.

Chenery (1958) emphasized three defects, in the free price mechanism, which prevent the attainment of the maximum social welfare (Pareto optimum position):

1. departure from perfect competition,
2. dynamic effects, and
3. equity considerations -- reduction of income inequalities.

These causes lead to structural disequilibrium in factor use; especially this phenomenon has been observed in the under-developed countries where labor tends to be over-valued and capital and foreign exchange undervalued; thus diversion between the market prices of commodities and their social values exists. Labor and natural resources in some projects may become limiting relatively to capital and economies of scale may be present in the economy. These conditions limit the use of the capital-output ratio as the sole criterion for investment allocation.

<u>Capital-labor ratio</u>

Capital-labor ratio test derived from Heckscher (1949) and Ohlin (1935) version of comparative cost doctrine is another criterion often proposed. It is suggested that where labor is abundant, techniques with low capital-labor ratio may be preferred. This does not assume, as in the capital-output ratio, that labor has a zero opportunity cost, and it tends to suggest the use of the factors of production in the proportion in which these are available. But it does not take into account the natural resources.

Social marginal productivity criterion

Social marginal product of capital, as proposed by Kahn (1951), is defined as the net contribution of the project to the national product. The projects may be ranked in order of SMP and preference may be given according to these ranks. The cost and output streams could be discounted to the present to take into account the effect of time.

Chenery (1953b) has made some modifications in SMP criterion to allow for artificial elements in the price system (tariffs, subsidies, et cetera) and to provide for the evaluation of labor and foreign exchange at opportunity cost rather than at market value and commodities both as outputs and inputs at social values. SMP in the form of activities (1958) is

$$(6.13) \quad (SMP)_j = \frac{(\sum_i a_{ij} P_i + L_j P_L)}{K_j} ,$$

where P_i and P_L are estimated accounting (equilibrium) prices of commodity output and inputs i, and labor respectively. a_{ij}, L_j, K_j are input coefficients of commodity i, labor, and capital per unit of activity j. The input coefficients have a minus sign. He suggests the procedure for working out the accounting prices.

Marginal reinvestment criterion

The marginal reinvestment criterion is suggested by Galenson and Leibenstein (1955). The objective is to maximize per capita income at some time in future as opposed to SMP criterion which pins its attention on the present.

Marginal growth contribution criterion

Eckstein (1957) has attempted to reconcile the objectives of the SMP and marginal reinvestment criteria through the marginal growth contribution criterion. It is assumed that the social objective is to maximize the present value of the future consumption stream.

Linear programming criterion

The investment allocation criteria discussed above are partial in the sense that these consider the capital as the only scarce source. It may be possible that investment allocation by one of these rules may lead to scarcity of some other factor such as foreign exchange, natural resources, or of some particular commodities. These criteria thus at best may be useful for relatively small changes in the economy. Further, most of these criteria are based on market prices which do not in most cases correspond to opportunity costs of factors and social values of commodities.

The formulation of the problem in the linear programming framework, as we shall see in the following pages, does not suffer from the above mentioned weaknesses and the internal economies (increasing returns to scale within the project) and external economies of scale both technical and pecuniary can be taken care of.

The projects may be divided into

1. those which can be operated at the discrete levels, and
2. those which can be operated at any level (maybe having some minimum level).

Suppose a main project could be divided into three ranges with regard to its size: $L_1 - U_1$, $L_2 - U_2$, and $L_3 - U_3$.

It may be noted that the allocation of the inputs generated by different projects is determined outside the model. As for example, possible, optimum, or desirable land use pattern for areas to be irrigated on completion of an irrigation project is determined in advance. Similarly, the allocation of fertilizers to be produced by different projects is known. The unit of an activity will generally be a composite one. Taking an activity unit equivalent to one acre will mean that the acre will be growing a number of crops in some known proportions. The composition of outputs and so of inputs will thus generally vary with ranges $L_1 - U_1$, $L_2 - U_2$, and $L_3 - U_3$ within a main project.

The inputs per unit of activity corresponding to these ranges of a project are assumed constant within a range and different between ranges. Similarly, the composition of output per unit of an activity may change between these ranges. It may be due to different combination of inputs of capital, other resources, and commodities per unit of activity. A project may not be having such ranges corresponding to different costs per unit of an activity, but may be subject to minimum or maximum limits or both due to other restrictions such as natural resources. For the convenience of presentation, let us assume there are j projects and i ranges in each project. Each range will be represented by an activity, so there will be i x j activities. The selection of an activity unit is arbitrary.

If the life of the projects differ (or the import or export activities are to be included), K_j, the total capital requirement, can be replaced by D_j, the annual capital input per unit of an activity as:

$$M_j = \frac{K_j}{\text{years (life of the project)}}$$

The period for activity is one year, so the inputs and net outputs of the activity pertain to a year. X_j is the level of the activity and D_j the total capital required per unit of an activity. The capital inputs for an activity include current capital inputs annually and capital inputs on the corresponding project K_j, brought on annual basis (M_j).

The problem is now formulated as to minimize the annual capital input (could be total capital requirements) to meet the specified demands of the commodities consistent with the availability of other factors of production and other commodity inputs. In other words, it is a problem of balancing supply and demand of different commodities and factors of production. It is, thus, an operational counterpart of the balanced growth.

$$\text{(6.14)} \quad \text{Minimize} \sum_{i=1}^{n} \sum_{j=1}^{p} D_{ij} X_{ij} \qquad j(1, 2, \ldots, p) \quad i(1, 2, \ldots, n)$$

subject to

$$\text{(6.15)} \quad - \sum_{i=1}^{n} \sum_{j=1}^{p} a_{bij} X_{ij} \geq - R_b \qquad b(1, 2, \ldots, m)$$

$$\text{(6.16)} \quad \pm \sum_{i=1}^{n} \sum_{j=1}^{p} a_{cij} X_{ij} = R_c \qquad c(1, 2, \ldots, q)$$

$$(6.17) \quad a_{cij} X_{ij} \geq L_{cij} \qquad j(1, 2, \ldots, p)$$

$$(6.18) \quad - a_{cij} X_{ij} \geq - U_{cij} \qquad j(1, 2, \ldots, p)$$

$$(6.19) \quad X_{ij} \geq 0$$

The production surface is assumed to be forming a convex set. The first constraint pertained to resources such as labor, natural resources; a_{bij} is the amount of a resource required by the specified unit level in the range of the j th project. The meaning of the constraint becomes clear by inverting the inequality from greater than to less than by multiplying the terms with -1. It states that the utilization of a resource by all projects will not exceed the amount available.

The second restriction relates to the quantities of different commodities required to be produced, R_c. a_{cij} is the net amount of a particular commodity produced by a unit of an activity (+) and the amount utilized by a unit of another activity (-). The net amount available after deducting the input requirements of a commodity shall be equal to the amount specified R_c in the beginning. Almost for all the commodities produced in the system, the R_c has to be specified to determine accounting prices. R_c may be zero, as in case of intermediates.

The third and fourth constraints are incorporated to take account of upper and lower limits of the projects. The third one specifies the minimum level of i th range corresponding to the commodity level of L_{cij}, and the fourth indicates the upper level of the project corresponding to U_{cij}. L_{cij} and U_{cij} may be based on one major commodity yielded by a unit of an activity; the unit of an activity is composite as explained earlier. The main project, divided into discrete projects, will have for each such project the constraints like third and fourth. The projects which can be run at any level at a constant cost won't have any of the above-stated constraints. The projects for which only minimum or maximum levels have to be specified will have correspondingly third or fourth constraint.

The optimum solution of the system will yield the selection of projects and annual inputs of capital in terms of D_j. From the selection of projects and their size the total capital requirements on the whole can be determined. Had the coefficient K_j been relevant instead of D_j, the value of the objective function itself would have been equal to capital needed for these projects. Then the total capital requirements can be broken up into its components, for the project and required direct by activities.

The dual, as shall be seen below, indicates the accounting prices of resources and commodities. The units in which accounting prices are measured are those of the objective function of the primal problem (same for dual). The choice of units is arbitrary as the system only determines the relative prices. In the present case, the price of capital (marginal product) has been set at 1.0. The accounting prices are thus measured in terms of capital.

The objective function of the dual:

$$(6.20)\quad \text{Maximize:}\ \sum_{c=1}^{q} P_c R_c - \sum_{b=1}^{m} W_b R_b + \sum_{j=1}^{p} \sum_{c=1}^{q} \bar{P}_{Lcj} L_{cij}$$

$$- \sum_{j=1}^{p} \sum_{c=1}^{q} \bar{P}_{Ucj} L_{cij} \quad ,$$

where P_c, $\bar{P}_{L_{cj}}$, $\bar{P}_{U_{cj}}$ and W_b are accounting prices,

subject to

$$- \sum_{b=1}^{m} a_{bij} W_b \pm \sum_{c=1}^{q} a_{cij} P_c + \sum_{c=1}^{q} \bar{P}_{Lcj} a_{cij}$$

$$- \sum_{c=1}^{q} \bar{P}_{Ucj} a_{cij} \leq D_j \quad ,$$

$$(6.21) \quad \sum_{b=1}^{m} a_{bij} W_b + \underbrace{\sum_{c=1}^{q} a_{cij} P_c}_{\text{(commodity inputs)}} + \sum_{c=1}^{q} \overline{P}_{Lcj} a_{cij} + D_j$$

$$\geq \underbrace{\sum_{c=1}^{q} a_{cij} P_c}_{\text{(commodity outputs)}} + \sum_{c=1}^{q} \overline{P}_{Ucj} a_{cij} \quad \text{, and}$$

$$(6.22) \quad P_c, W_b, \overline{P}_{Lcj} \text{ and } \overline{P}_{Ucj} \geq 0 \quad .$$

The equality sign will hold good in the above relation for those projects with positive level at the optimum solution. If no minimum and maximum limits are specified for the project, the third and fourth terms on the left hand side of Relation 6.21 will be zero. Then

$$(6.23) \quad \sum_{b=1}^{m} a_{bij} W_b + \underbrace{\sum_{c=1}^{q} a_{cij} P_c}_{\text{(commodity inputs)}} + D_j$$

$$= \underbrace{\sum_{c=1}^{q} a_{cij} P_c}_{\text{(commodity outputs)}}$$

This equation holds true also for those projects for which minimum and maximum limits specified are not effective (binding). It means

$$L_{cij} < a_{cij} X_{ij} < U_{cij}$$

If $a_{cij} X_{ij} = L_{cij}$, then $\bar{P}_{Lcj}$ is greater than zero, otherwise it is zero. Similarly, if $a_{cij} X_{ij} = U_{cij}$, $\bar{P}_{Ucj}$ is greater than zero. Either $\bar{P}_{Lcj}$ or $\bar{P}_{Ucj}$ can be greater than zero for a project as both maximum and minimum limits can't be effective at the same time.

To clarify the relation, it is assumed that the project produces only one product and the activity limit corresponding to that has been specified as $a_{cij} = 1$ unit of a commodity. Then

$$(6.24) \quad \sum_{b=1}^{m} a_{bij} W_b + \underbrace{\sum_{c=1}^{q} a_{cij} P_c}_{\text{(commodity inputs)}} + D_j = P_c + \bar{P}_{Lcj} - \bar{P}_{Ucj}$$

In case minimum limit is binding, the adjusted accounting price is $P_c + \bar{P}_{Lcj}$, ($\bar{P}_{Ucj} = 0$). It means that P_c has to be raised by $\bar{P}_{Lcj}$, to make the commodity produced at least at the minimum level of the project.

If the maximum limit is binding, the adjusted accounting price will be $P_c - \overline{P}_{Ucj}$, ($\overline{P}_{Lcj} = 0$). It is due to the fact the commodity can't be produced beyond a certain quantity due to an upper limit on the size of the project. A cut in P_c is required such that the commodity won't surpass the upper limit of the project. $\overline{P}_{Lcj}$ and $\overline{P}_{Ucj}$ are thus the adjustment factors for accounting price of a commodity due to limitations on the size of a project in the system.

More often than not, there will be some inputs of commodities used which are not produced by the projects under reference, the internal structure of some industries producing these commodities used as inputs having been omitted from this model. No restriction on these inputs has been put. Prices of these inputs in terms of capital are estimated outside the model from the conditions obtaining in the country or from the general model run for the economy as a whole. The costs on those inputs are to be included in the objective function (6.10) by addition of another term,

$$\sum_{L=1}^{N} \sum_{J=1}^{P} \gamma_{ij} X_{ij} \quad .$$

γ_{ij} is the cost on items other than on capital.

Similarly, if required, the model can be freed from labor restriction and the labor inputs may then be valued, on the basis of labor value in terms of capital inputs given from outside the model; the price of a capital input has been set arbitrarily at 1 in the model.

The decision on inclusion of restrictions on labor or any other resource or other inputs in the model depends upon the magnitude of changes to be made in the economy. The feasibility of the model can always be tested after the solution, and in cases the restrictions of any one of the factors or commodities not included have been surpassed, the corresponding restrictions can be specified afterwards.

The subdivision of main projects into relevant ranges makes it possible to account for economies of scale (technical). Further, the determination of accounting prices of interdependent commodities in the model and of resources for which restrictions have been specified leads to inclusion of the impact of investment on input prices. It amounts to the inclusion of the impact pecuniary external economies in the model.

The project integration will be a part of the model, depending on the scope specified for the model. The model can be extended to reflect some other indirect and subsidiary effects so far as these could be quantified.

The model so far does not exclude the possibility of entering in the final solution more than one range of the same project. This is not a practical possibility. Adjustments in the final solution will be required to be made in cases where there are more than one range of the same project in the final solution. It may be relatively less expensive than to incorporate additional restrictions to eliminate the above-mentioned possibility. The additional restrictions to be included in the model for this purpose would be:

(6.25) $0 \leq P_j \leq 1$

P_j is an integer variable;

$P_j = 0$, j th project out of the solution;

$P_j = 1$, j th project in the solution.

(6.26) $P_j = V_{1j} + V_{2j} \ldots V_{ij} \ldots + V_{nj}$

(6.27) $0 \leq V_{ij} \leq 1$

V_{ij} is also an integer variable;

$V_{ij} = 0$, i th range of j th project out of solution;

$V_{ij} = 1$, i th stage of j th project in the solution.

The above-mentioned restrictions pertain to integer programming, part of the model. The Restrictions 6.17 and 6.18 of the model will also undergo a change as

$$L_{cij} V_{ij} \leq a_{cij} X_{ij} \leq U_{cij} V_{ij}$$

To make exposition of the model more clear, the model is summarized with one more adjustment. The activity X_{ij} pertaining to i th range of j th project which is composite one has been changed here to X_{cij}, representing acreage of c th crop in i th range of j th project. Now each crop has one activity. A_{ij} is the total area to be covered by the stage of j th project, π_{cij} is the proportion of total area, A_{ij}, under the c th crop. All other notations are the same.

(6.28) Minimize $\sum\limits_{i}\sum\limits_{j} A_{ij}\, D_{ij} + \sum\limits_{c}\sum\limits_{i}\sum\limits_{j} Y_{cij}\, X_{cij}$

subject to

(6.29) $\sum\limits_{c}\sum\limits_{i}\sum\limits_{j} a_{bcij}\, X_{cij} \leq R_b$

(6.30) $\pm \sum\limits_{i}\sum\limits_{j} a_{cij}\, X_{cij} = R_c$

(6.31) $L_{ij}\, V_{ij} \leq A_{ij} \leq U_{ij}\, V_{ij}$

(6.32) $P_j = \sum\limits_{i} V_{ij}$

(6.33) $0 \leq V_{ij} \leq 1$ V_{ij} is an integer variable

(6.34) $0 \leq P_j \leq 1$ $\qquad P_j$ is an integer variable

(6.35) $x_{cij} = \pi_{cij} A_{ij}$

(6.36) $A_{ij}, X_{cij} \geq 0$

The linear programming model is termed as equivalent to benefit-cost ratio. The commodities and factors are valued at the opportunity cost in terms of capital. At the optimal allocation, the (net) social profit is zero, the benefit-cost ratio will be equal to 1. The SMP criterion, using the same accounting prices as that used in the model, will give the same ratio (equal to 1), as may be seen from equation for SMP. If the accounting prices in the economy are known from a general model discussed in Chapter V, then the investment allocation decision can be easily made on the basis of SMP criterion. It does not require that the marginal productivity of capital should be known. For non-optimal activities these two criteria, linear programming and SMP, may not agree for ranking.

The system pertains to the closed economy. It can be made suitable for the open economy by incorporating in it import and export activities, each for the relevant commodities. The foreign exchange will be added as a restriction in this case. The dual would yield, then, the accounting prices of the foreign exchange.

VII. RESULTS OF SOME PROGRAMS

It is proposed to discuss in this chapter the results of some programs relating to Indian agricultural economy. Models D and E, presented in Chapter VI, are modified to suit the availability of data for these programs.

Primal

$$(7.1) \qquad \text{Max:} \sum_{L=1}^{U} \sum_{J=1}^{P} C_j^L X_j^L \quad ,$$

where U = 17 regions, 15 provinces, and 2 Union territories,

P = 16 crops: 1, 2, ..., 8 are food grains; 9 is sugarcane, 10 is cotton, 11 is jute; and 12, 13, ..., 16 are oil seeds,

subject to

$$(7.2) \qquad - X_j^L \leq - A_{j(min)}^L$$

$$(7.3) \qquad X_j^L \leq A_{j(max)}^L$$

$$(7.4) \qquad \sum_{j=1}^{P} X_j^L = A^L$$

(7.5) $$- \sum_{j=1}^{P} c_j^L \, X_j^L \leq - I^L$$

(7.6) $$- \sum_{L=1}^{U} \sum_{j=1}^{8} y_{j(f)}^L \, X_{j(f)}^L \leq - F$$

(7.7) $$- \sum_{L=1}^{U} y_{j(s)}^L \, X_{j(s)}^L \leq - S$$

(7.8) $$- \sum_{L=1}^{U} y_{j(c)}^L \, X_{j(c)}^L \leq - C$$

(7.9) $$- \sum_{L=1}^{U} y_{j(g)}^L \, X_{j(g)}^L \leq - G$$

(7.10) $$- \sum_{L=1}^{U} \sum_{j=12}^{16} y_{j(o)}^L \, X_{j(o)}^L \leq - O$$

(7.11) $$X_j^L \geq 0$$

India has been divided into fifteen states and two union territories, Delhi and Himachal pradesh, for the model. The regions account for 99.3 per cent of population, 98.7 per cent of geographical area and 99.8 per cent of total cropped area of the country. The reason for leaving areas belonging to remaining four union territories is lack of adequate data.

The production activities of the model are the following crops, divided into five groups:

1. rice
2. jowar
3. bajra
4. maize
5. ragi
6. wheat
7. barley
8. gram
9. sugarcane
10. cotton
11. jute
12. groundnut
13. castorseed
14. sesamum
15. rape and mustard
16. linseed

The first eight are food grains and the last five (12 to 16) are oil seeds. Sugarcane (9), cotton (10), and jute (11) could be broadly termed as commercial crops. These sixteen crops, taken together, account for slightly more than 77 per cent (287.923 million acres) of the cropped area annually (371.9 million acres). The corresponding percentage of cropped area covered by these sixteen crops in different regions varies from 72 to 87, with the only exception being Kerala. In this case the percentage of cropped area covered is only 37. This is because of the fact that there are extensive areas under coconuts, fruits and vegetables, et cetera, in this region. The remaining area is under fodders, small millets, other pulses, achards, et cetera. The important single category in the remaining area is fodder. It is reasoned in Chapter VI that leaving out fodder area and the livestock activities from programs fairly balances one another. Thus regions and production activities taken into account in the programs largely cover the crop production sector of the agricultural economy. The livestock production sector is not so important from its contribution to the national income.

C_j^L in the models presented in Chapters V and VI are net incomes of the production activities occurring to those resources for which restrictions are incorporated in the model. Farm management investigations (Government of India, 1957) conducted in the country have shown that cash expenses form a very small proportion of the total expenses in crop production, when total expenses account for all out-of-pocket expenses and imputed values of resources owned by farmers and employed on the farm. Among the cash expenses again land revenue and irrigation charges to be paid to the government are important items. These are to be paid anyway, whether the existing cropping pattern is continued or some changes within reasonable limits are made in it. Thus it seems that either the program is run with C_j^L pertaining to net income or C_j^L indicating gross income, it will not substantially change the resulting cropping pattern from the programs. The difficulty of estimating the net incomes of crops, due to lack of sufficient data for each state, thus has been overcome through using C_j^L indicating the gross income.

C_j^L is the income per acre from the j th activity in Region L. It has been worked out by multiplying the yield per acre of the main produce, as for example grains for food grains, with the corresponding price per 'maund' of the commodity in the region. Byproducts from crops are mainly used as roughages for animal food, fuel for household cooking, et cetera.

X_j^L is the level of activity j, i.e. number of acreages to be grown under the j th crop. Constraints 7.2 and 7.3 are the minimum and maximum area constraints within which the acreage of a crop can vary in a region. These constraints are discussed in detail in Model D presented in Chapter VI.

The maximum and minimum area limits tried in the model are ± 10%, ± 20% and ± 40% of the average area under the particular crop during the second plan period, 1956-57 to 1960-61. These limits hold good for each crop except for sugarcane, for which the corresponding changes allowed are ± 10%, ± 10% and ± 20%. The rate of change is zero for sugarcane when other crops are allowed to change from ± 10% to ± 20%. The change for sugarcane is half (± 10% to ± 20%) when other crops are allowed to change their acreage from ± 20% to ± 40%. This has been done since sugarcane is a year-round crop, whereas other crops are seasonal ones. The changes in acreages should have been allowed in the programs on the basis of the soil surveys, irrigation facilities available, et cetera. But in the absence of adequate soil survey data for this purposes, these limits of ± 10%, ± 20% and ± 40% are specified.

The first limit, ± 10%, may be taken as a conservative one, indicating the effect on production if small changes are allowed in the cropping pattern. The second limit, ± 20%, is a quite moderate one. It will indicate the improvement in production levels possible with moderate changes of the magnitude of ± 20% in the acreages during 1956-57 and 1960-61. The third limit, ± 40%, may not be possible in some cases under the existing technology and without addition of some other resources. Anyway, this limit is interesting in the sense that it shows in general how the results of production programs vary if change is allowed up to this limit. It bears mention here that the resulting cropping patterns of the programs if in some regions for higher changes in areas, namely $\pm$ 40%, are found not completely practical within overall cropped area in a region, specified for the program, the cropped areas left outside the programs may provide a safety valve for required adjustments.

Constraint 7.4 pertains to the availability of total acreage for these sixteen crops in a region. The level of A^L corresponds to the average acreage under these sixteen crops during the plan period 1956-57 to 1960-61.

Restriction 7.5 states that the income from agriculture (gross value of crops) in a region is not permitted to fall below the certain minimum level, I^L. I is the income from these sixteen crops in a region based on the production coefficients and prices used for a program.

Restrictions 7.6 to 7.10 are availability constraints at the national level. 7.6 corresponds to food grains, 7.7 to sugarcane, 7.8 to cotton, 7.9 to jute and 7.10 to oil seeds. The levels of these restrictions are based on production coefficients employed for different sets of programs.

y_j^L, production coefficients involved in Restrictions 7.6 to 7.10, need explanation. These are the simple average yield per acre of five years of the second plan period for programs relating to 1957-61. The other alternatives were either to use regression estimates or weighted average estimates of yields per acre, the weights being the average under the crop in a region in each year. Five years seems to be a small period for regression estimates; while weighted estimates would have been biased ones. The simple average estimates for y_j^L were, therefore, computed and the levels of I^L, F, S, C, G, O are correspondingly adjusted in programs and so also the C_j^L. Thus the regional income constraints and national availability constraints will be slightly different from the average regional income levels and average production levels attained during the second plan. These latter estimates are based on weighted averages, weights being the acreages under different crops during the second plan period. Y_j^L for programs pertaining to 1960-61 correspond to the same single year.

In short, the model discussed proposes to maximize the gross income from agriculture sector of the economy from the existing regional acreages available, not allowing the regional incomes to fall below those already attained and not permitting the production of food grains, sugarcane, cotton, jute, and oil seed to go below the levels reached earlier for the country as a whole. The reallocation of land among crops in a region is kept within the limits specified above.

Dual

It may be useful to examine the dual of the model.

$$(7.12)\quad \text{Min: } \sum_{L=1}^{U} \gamma^L A^L - \sum_{L=1}^{U} \sum_{j=1}^{P} \gamma^L_{j(min)} A^L_{j(min)}$$

$$+ \sum_{L=1}^{U} \sum_{j=1}^{P} \gamma^L_{j(max)} A^L_{j(max)} - \sum_{L=1}^{U} \delta^L I^L - P_f F - P_s S$$

$$- P_c C - P_g G - P_o O$$

subject to

$$(7.13)\quad \gamma^L - \gamma^L_{j(min)} + \gamma^L_{j(max)} - \delta^L C^L_j - P_f y^L_{j(f)} - P_s y^L_{j(s)}$$

$$- P_c y^L_{j(c)} - P_g y^L_{j(g)} - P_o y^L_{j(o)} \geq C^L_j$$

or

$$\gamma^L - \gamma^L_{j(min)} + \gamma^L_{j(max)} \geq C^L_j + \delta^L C^L_j + P_f y^L_{j(f)}$$

$$+ P_s y^L_{j(s)} + P_c y^L_{j(c)} + P_g y^L_{j(g)} + P_o y^L_{j(o)}$$

(7.14) $\gamma^L, \gamma^L_{j(max)}, \gamma^L_{j(min)}, \delta^L, P_f, P_s, P_c, P_g, P_o \geq 0$

γ^L is the general gross rent of the land per acre in a region. $\gamma^L_{j(min)}$ is the specific rent for those crops touching the minimum acreage limits. The income for those crops has to be raised through subsidies and such other programs by this amount to keep them in the program, or the rent has to be decreased by that amount. $\gamma^L_{j(max)}$ is the specific rent for those crops touching the maximum area limits. In this case the excessive rent could be "taxed out". Either maximum or minimum area constraints will be effective; both cannot be binding at the same time. $-\gamma^L_{j(min)}$ and $\gamma^L_{j(max)}$ are the amounts by which the overall rent γ^L in a region is required to be adjusted to arrive at the gross rent per acre of a particular crop. This is equal to

$$\gamma^L - \gamma^L_{j(min)} + \gamma^L_{j(max)}$$

This information can be used to arrive at net rent, all other factors paid out from the gross rent at the rate equal to their opportunity cost or some other relevent principles. In general, returns of other factors than land employed will not exceed γ^L; therefore it will not disturb in any way the specific rents to crops, $-\gamma^L_{j(min)}$ and $\gamma^L_{j(max)}$. The information on rent is very much sought after in the country for formulating various government policies at the national and state levels.

δ^L is the proportion by which the income per acre of a certain commodity shall be raised in order to meet the minimum income level specified for a region. In other words it is the gross rent per acre for a crop is to be reduced by $\delta^L C_j^L$ to encourage a crop acreage sufficient to meet the minimum level of income. Income support programs for a region could be based on δ^L. If the regional income constraint is not effective δ^L is zero.

The explanation for P_f, P_s, P_c, P_g, and P_o are the same. These represent the subsidy prices per unit of a commodity to meet the national requirements of commodities specified restrictions of the model. The level of subsidies per unit of commodity will be the same all over the country but will be different if converted on a per unit area basis so far as yields per acre for a commodity are different in different regions. In case a national constraint is not limiting its corresponding subsidy price would be zero.

Programs

Two sets of prices and two sets of production coefficients were used for the model. These two sets thus give rise to four programming solutions. Each main program was run at three levels of changes in area: ± 10%, ± 20% and ± 40% (for sugarcane ± 10%, ± 10% and ± 20%). Hence, the total number of programming models, therefore, is twelve.

Prices

The two sets of prices as mentioned earlier were used:

Regional prices model (Regional harvest prices of commodities for the period 1956-57 to 1960-61) The regional prices used for different commodities are the simple average of harvest prices ruling during the second plan period, 1956-57 to 1960-61. The differences in the harvest prices of a commodity in different regions may be mainly due to transport cost further supplemented by quality differences, government price policy, et cetera. The use of these prices does take into account, indirectly but to an appreciable extent, the transport cost of a commodity from one region to another.

National prices model (Average harvest prices at the national level of different commodities during the period 1956-57 to 1960-61) The average harvest price of a commodity at the national level is the weighted average price of regional prices, the weights being production of the commodity in different regions. In using this set of prices it is assumed that the same price for a commodity could, through government policies, rule all over the country. Yield differentials for the same commodity in different regions only determine the shifts in acreages for the same commodity for this model. The shifts in acreages in programs using regional prices in the model above will be due to different yields as well as different prices in the various regions. The impact on adjustments in acreages due to differentials in prices among regions for the same commodity has been eliminated in programs using national prices. But national prices still do play a role in substitution between crops. It will be of interest to compare results of programs using national prices with those obtained using regional prices.

Production coefficients

Two sets of production coefficients are used:

a. average yield per acre of different crops over the period 1956-57 to 1960-61,

b. yield per acre of different crops in 1960-61.

The period 1956-57 to 1960-61 is the period covered by the second five year plan and 1960-61 is the base year for the third plan. The level of agricultural production in the country is subjected to variations of considerable magnitudes on account of natural factors, such as rainfalls, temperatures, et cetera. The coefficients based on five years are likely to be more consistent than those based on one year. However, it will be of interest to compare results flowing from programs using these two sets of production coefficients. The best thing would have been to use coefficients pertinent to the changes in areas, viz., ± 10%, ± 20% and ± 40%. Such information is not available at present. The feasible alternative thus seems to be to fall on those average coefficients, making the assumption of constant returns.

Number of programs

To make the presentation of results of these twelve programs easier, it will be useful to name these programs.

A. RP(1957-61): Programs using regional prices and production coefficients of the period 1956-57 to 1960-61

1. RP(1957-61) ± 10%, relating to ± 10% changes in acreages
2. RP(1957-61) ± 20%, relating to ± 20% changes in acreages
3. RP(1957-61) ± 40%, relating to ± 40% changes in acreages

B. NP(1957-61): Programs using national prices and production coefficients relating to the period 1956-57 to 1960-61

4. NP(1957-61) ± 10%, relating to ± 10% changes in areas
5. NP(1957-61) ± 20%, relating to ± 20% changes in areas
6. NP(1957-61) ± 40%, relating to ± 40% changes in areas

C. RP(1960-61): Programs using regional prices, but production coefficients based on year 1960-61

7. RP(1960-61) ± 10%, relating to ± 10% changes in areas

8. RP(1960-61) ± 20%, relating to ± 20% changes in areas

9. RP(1960-61) ± 40%, relating to ± 40% changes in areas

D. NP(1960-61): Programs using national prices, but production coefficients of the year 1960-61

10. NP(1960-61) ± 10%, relating to ± 10% changes in areas

11. NP(1960-61) ± 20%, relating to ± 20% changes in areas

12. NP(1960-61) ± 40%, relating to ± 40% changes in areas

Size of programs (467 x 214)

There are seventeen regions and sixteen potential crops for the various models. However, not all the crops are grown in all of the regions. Further, if the production level of a crop is less than 500 metric tons in a region, the corresponding crop activity has been left outside the program. The number of activities in the programs, finally, is 214 instead of 272 (16 x 17).

There are 467 rows in the programs. Two hundred fourteen are each for restrictions of the types 7.2 and 7.3 There are 17 each for Restriction 7.4 and Restriction 7.5. Five rows are for national restrictions corresponding to 7.8.

The number of rows was actually reduced by 214 (467 - 214 = 253) for running the programs. The maximum and minimum restrictions were combined into one by running the programs for $\pm$ 10%, $\pm$ 20% and $\pm$ 40% ranges rather than for the whole area under consideration. It means whatever could be produced at the minimum level of the activities over 90 per cent of the total area in the case of $\pm$ 10% limits, over 80 per cent of the total area in the case of $\pm$ 20% of changes and over 60 per cent of the total area for $\pm$ 40% ranges were left outside the solutions of programs.

$$(7.15) \quad U^L_j = X^L_j - A^L_{j(min)}$$

It has been accomplished by the above-mentioned transformation of X^L_j original variable to U^L_j, the transformed variable. $A^L_{j(min)}$ is the minimum level of acreage which crop j can occupy in Region L. The backward transformations were made to convert the solutions in terms of the original variable X^L_j.

Each of the main four programs mentioned as A, B, C and D were run parametrically for $\pm$ 10%, $\pm$ 20% and $\pm$ 40% changes in area. This modification also resulted in greatly reducing the computational burden, as may be seen from Table 14.

The computor had to complete only one more additional iteration in moving the optimum result from RP(1957-61) $\pm$ 10% to RP(1957-61) $\pm$ 20%. Additional iterations were not required within the remaining three main programs to attain the optimum

Table 14. Number of iterations for different programs

No.	Program	No. of iterations
1	RP(1957-61) ± 10%	141
2	RP(1957-61) ± 20%	142
3	RP(1957-61) ± 40%	142
4	NP(1957-61) ± 10%	280
5	NP(1957-61) ± 20%	280
6	NP(1957-61) ± 40%	280
7	RP(1960-61) ± 10%	151
8	RP(1960-61) ± 20%	151
9	RP(1960-61) ± 40%	151
10	NP(1960-61) ± 10%	193
11	NP(1960-61) ± 20%	193
12	NP(1960-61) ± 40%	193

solution for higher levels of changes in acreages, i.e. ± 20% and ± 40% from the corresponding solutions for ± 10% changes in acreages.

Levels of restrictions for programs

Income and area restrictions The minimum levels of incomes (7.5) for different programs based on production coefficient used and type of prices employed are set side by side in Table 15. The acreages available in each region incorporated in programs as Restriction 7.4 are included there to give an idea of distribution of total acreages and total value of crops under consideration among regions.

Table 15. Basic level of incomes for different regions for crop production, in million rupees (income restrictions for different programs)

No.	Region	Area in million acres	RP(1957-61) original income	NP(1957-61) original income	RP(1960-61) original income	NP(1960-61) original income
1	Andra Pradesh	21.475	3399.3970	3144.2624	3335.8861	3074.7100
2	Assam	5.064	787.2231	984.6658	755.8817	949.1181
3	Bihar	20.157	2883.8870	2708.7504	3227.9215	3031.0595
4	Guzrat	18.807	1681.5627	1606.8162	1860.9850	1767.0295
5	Jamu and Kashmir	1.474	198.8532	209.9398	195.2687	206.6815
6	Kerala	2.047	390.9836	489.5632	421.5347	528.7031
7	Madhya Pradesh	33.436	3471.4419	3648.2715	3665.3752	3888.5985
8	Madras	13.139	2844.9768	2808.0493	2898.9169	2860.1935
9	Maharashtra	35.563	3387.9159	3348.5716	3740.6348	3701.9402
10	Mysore	18.703	1949.2808	1829.9714	1968.3787	1845.0726
11	Orissa	10.711	1539.3187	1401.0614	2112.0896	1916.5229
12	Punjab	19.891	2783.2136	2980.6581	2921.5457	3130.6804
13	Rajasthan	24.971	1852.7152	1811.8148	1808.6548	1769.5497
14	Uttar Pradesh	48.385	5964.3324	6492.0219	6417.7949	7020.3214
15	West Bengal	12.983	2846.8113	2541.9294	3187.7529	2847.3939
16	Delhi	0.237	21.7497	21.5584	27.7508	27.3760
17	Himachel Pradesh	0.880	122.2734	106.2889	120.2324	105.0999
	Grand total	287.923	36125.9300	36134.1860	38666.5960	38670.0410

National production restrictions The quantities of commodities grouped into five categories, each corresponding to one constraint, 7.6 - 7.10, are tabulated in Table 16. The production levels in all cases except oil seeds are higher for 1960-61 than those for 1957-61.

Results of programs

The results of the twelve programs are very voluminous. The optimum cropping plan of a region, and production and income therefrom, could be accomodated in a one-page table having about 57 cells. All the results would thus require 288 such pages. It is, therefore, proposed to give here the consolidated results of the programs at the national level only. The regional figures will be reported separately in some form later.

Overall income for programs The levels of income (gross value of crops) accrueing from different programs are reported in Table 17.

On the whole ± 10% changes lead to about 3 per cent increases in incomes over the corresponding basic figures, ± 20% shifts raise this figure to 6 per cent and ± 40% adjustments in acreages further enhance this increase to about 12 per cent. Comparisons of RP and NP programs for each period indicate that increases in incomes are slightly less in the case of latter price-basis over corresponding original values.

Table 16. Production of different groups of commodities for all regions with production coefficients based on 1957-61 and on 1960-61, in million mds

No.	Commodity group	% of total acreage	Production on 1956-61 basis	Production on 1960-61 basis	Production on 1960-61 basis as % of 1957-61 basis
1	Food grains	79.80	1750.7965	1876.7155	107.19
2	Sugarcane	1.80	202.2547	210.0626	103.86
3	Cotton	6.78	66.2585	79.1604	119.47
4	Jute	0.60	21.2521	21.8779	102.94
5	Oil seeds	11.02	172.2369	164.9485	95.77

Table 17. Income from crops for different programs for all regions

Sno.	Program No.	Program Name	Income	Percentage increase in income over original
1	-	RP(1957-61) original	36125.930	-
2	1	RP(1957-61) ± 10%	37369.570	3.44
3	2	RP(1957-61) ± 20%	38336.308	6.12
4	3	RP(1957-61) ± 40%	40544.925	12.23
5	-	NP(1957-61) original	36134.186	-
6	4	NP(1957-61) ± 10%	37342.514	3.34
7	5	NP(1957-61) ± 20%	38283.106	5.95
8	6	NP(1957-61) ± 40%	40430.131	11.89
9	-	RP(1960-61) original	38666.596	-
10	7	RP(1960-61) ± 10%	40017.960	3.49
11	8	RP(1960-61) ± 20%	41083.579	6.25
12	9	RP(1960-61) ± 40%	43498.782	12.50
13	-	NP(1960-61) original	38670.041	-
14	10	NP(1960-61) ± 10%	39988.266	3.41
15	11	NP(1960-61) ± 20%	41033.864	6.11
16	12	NP(1960-61) ± 40%	43395.787	12.22

The improvements in incomes from programs using both sets of production coefficients (1957-61 and 1960-61) compare fairly well with each other, though basic levels of incomes for 1957-61 and 1960-61 differ appreciably. It indicates that wide differences in the overall cropping pattern resulting from program solutions using two sets of production coefficients are not expected. This aspect is discussed further in the set of tables in the forthcoming pages.

Table 18. Income from different commodity groups for RP(1957-61) programs for all regions, in million rupees

Sno	Commodity groups	Original	RP(1957-61) ± 10% Income	%Inc[a]	RP(1957-61) ± 20% Income	%Inc[a]	RP(1957-61) ± 40% Income	%Inc[a]
1	Food grains	26795.1030	27369.9470	2.14	27985.0170	4.44	29173.6040	8.88
2	Sugarcane	3277.7643	3605.5403	10.00	3605.5403	10.00	3933.3173	20.00
3	Cotton	2208.0589	2337.2864	5.85	2467.9370	11.77	2727.8151	23.54
4	Jute	518.9012	570.7913	10.00	622.6814	20.00	726.4613	40.00
5	Oil seeds	3326.1071	3486.0083	4.81	3655.1344	9.89	3983.7300	19.77

[a]Percentage increase over original.

Table 19. Income from different commodity groups for NP(1957-61) programs for all regions, in million rupees

Sno	Commodity groups	Original	NP(1957-61) ± 10%		NP(1957-61) ± 20%		NP(1957-61) ± 40%	
			Income	%Inc[a]	Income	%Inc[a]	Income	%Inc[a]
1	Food grains	26798.1190	27419.9480	2.32	28055.6090	4.69	29311.6550	9.38
2	Sugarcane	3277.8647	3605.6506	10.00	3605.6506	10.00	3933.4378	20.00
3	Cotton	2208.2596	2337.0424	5.83	2466.9050	11.71	2725.5509	23.42
4	Jute	519.2521	571.1773	10.00	623.1025	20.00	726.9526	40.00
5	Oil seeds	3330.6943	3408.6997	2.34	3531.8416	6.04	3732.5400	12.06

[a]Percentage increase over original.

Table 20. Income from different commodity groups for RP(1960-61) programs for all regions, in million rupees

Sno	Commodity groups	Original	RP(1960-61) ± 10% Income	%Inc[a]	RP(1960-61) ± 20% Income	%Inc[a]	RP(1960-61) ± 40% Income	%Inc[a]
1	Food grains	28877.3990	29516.9640	2.21	30207.0680	4.60	31535.3850	9.20
2	Sugarcane	3402.7329	3742.9371	9.99	3742.9371	9.99	4083.1425	19.99
3	Cotton	2652.6169	2821.7219	6.37	2991.6927	12.78	3330.7688	25.56
4	Jute	531.7114	584.8825	10.00	638.0537	20.00	744.3956	40.00
5	Oil seeds	3202.1403	3351.4587	4.66	3503.8312	9.42	3805.0935	18.83

[a]Percentage increase over original.

Table 21. Income from different commodity groups for NP(1960-61) programs for all regions, in million rupees

Sno	Commodity groups	Original	NP(1960-61) ± 10% Income	%Inc[a]	NP(1960-61) ± 20% Income	%Inc[a]	NP(1960-61) ± 40% Income	%Inc[a]
1	Food grains	28832.1740	29489.7220	2.28	30167.5210	4.63	31501.4160	9.26
2	Sugarcane	3404.4051	3744.7800	9.99	3744.7800	9.99	4085.1558	19.99
3	Cotton	2637.9427	2844.0473	7.81	3051.1420	15.66	3464.3412	31.32
4	Jute	534.5399	587.9939	10.00	641.4478	20.00	748.3555	40.00
5	Oil seeds	3260.9839	3321.7266	1.86	3428.9759	5.15	3596.5224	10.29

[a]Percentage increase over original.

Income from different commodity groups for programs

The overall incomes of different programs are split up into five commodity groups for which national restrictions were stated in the programs.

The increases in income for sugarcane and jute are to the maximum extent (nearly maximum in case of sugarcane for 1960-61 programs) considering the changes allowed for in acreages under these crops. The third in order of increases in income is cotton, followed by oil seeds and food grains. The rate of increase experienced by cotton is slightly more than half the changes in areas for 1957-61 programs. The corresponding improvements in income for cotton are about 2/3 of the changes in areas for 1960-61 programs. As regards the comparisons between RP and NP programs within each period, NP(1960-61) shows considerable improvements over RP(1960-61) for cotton, while this is not so for 1957-61 programs.

There is a substitution in incomes between oil seeds and food grains with changes in price bases. RP programs favor oil seeds in this respect at the cost of food grains, whereas in NP programs, it is turned the other way around. As a result, the rise in incomes for oil seeds is less for NP programs as compared to those for RP programs. The rise in incomes for oil seeds in the case of the latter programs approximates 1/2 of the changes allowed for in areas.

Despite the above-mentioned fact, the improvements in incomes for food grains covering about 80 per cent of the area under discussion are the lowest, both in the case of RP and NP programs. It is interesting to note that the rises in incomes experienced by food grains and oil seeds using the same set of prices but different production coefficients (e.g. RP(1957-61) and RP(1960-61)) compare fairly well with each other.

<u>Production levels for programs</u> The levels of production of five groups are indicated in Tables 22 - 25. As in the case of results of incomes, the improvements brought about in production are in the same order: jute, sugarcane, cotton, oil seeds and wheat. The relative gains in production for sugarcane and jute are the same as that for their respective rises in incomes. These have reached the maximum possible limits (approximately maximum for sugarcane in 1960-61 programs) allowed for in the programs. The additional production expressed as percentages over original production, in the case of cotton are the same for corresponding income increases for NP programs. It is so because the same price is kept for all regions in NP programs. If RP programs are considered, the increases in incomes for cotton are slightly better than those for production. Gains in the production of cotton in NP programs over RP programs are marked for 1960-61 as compared to 1957-61.

The improvements in production for oil seeds and food

Table 22. Production of different commodity groups for RP(1957-61) programs for all regions, in million mds

Sno	Commodity group	RP(1957-61) original	RP(1957-61) ± 10% Quantity	RP(1957-61) ± 10% %Inc[a]	RP(1957-61) ± 20% Quantity	RP(1957-61) ± 20% %Inc[a]	RP(1957-61) ± 40% Quantity	RP(1957-61) ± 40% %Inc[a]
1	Food grains	1750.7965	1722.2133	1.22	1796.6803	2.62	1842.4676	5.24
2	Sugarcane	202.2547	222.4801	10.00	222.4801	10.00	242.7056	20.00
3	Cotton	66.2585	70.0492	5.72	73.8861	11.51	81.5137	23.02
4	Jute	21.2521	23.3773	10.00	25.5024	20.00	29.7528	40.00
5	Oil seeds	172.2369	181.0039	5.09	190.1997	10.43	208.1365	20.84

[a]Percentage increase over original.

Table 23. Production of different commodity groups for NP(1957-61) programs for all regions, in million mds

Sno	Commodity group	NP(1957-61) original	NP(1957-61) ± 10%		NP(1957-61) ± 20%		NP(1957-61) ± 40%	
			Quantity	%Inc[a]	Quantity	%Inc[a]	Quantity	%Inc[a]
1	Food grains	1750.7965	1775.8582	1.43	1801.8034	2.91	1852.7141	5.82
2	Sugarcane	202.2547	222.4801	10.00	222.4801	10.00	242.7056	20.00
3	Cotton	66.2585	70.1226	5.83	74.0191	11.71	81.7798	23.43
4	Jute	21.2521	23.3772	10.00	25.5025	20.00	29.7528	40.00
5	Oil seeds	172.2369	177.8268	3.25	185.2868	7.58	198.3104	15.14

[a]Percentage increase over original.

Table 24. Production of different commodity groups for RP(1960-61) programs for all regions, in million mds

Sno	Commodity group	RP(1960-61) original	RP(1960-61) ± 10% Quantity	%Inc[a]	RP(1960-61) ± 20% Quantity	%Inc[a]	RP(1960-61) ± 40% Quantity	%Inc[a]
1	Food grains	1876.7155	1903.4736	1.42	1934.0915	3.05	1991.3719	6.11
2	Sugarcane	210.0626	231.0648	9.99	231.0648	9.99	252.0671	19.99
3	Cotton	79.1604	84.0906	6.23	89.0506	12.49	98.9409	24.99
4	Jute	21.8779	24.0657	10.00	26.2535	20.00	30.6291	40.00
5	Oil seeds	164.9485	173.0801	4.93	181.3942	9.97	197.8140	19.92

[a]Percentage increase over original.

Table 25. Production of different commodity groups for NP(1960-61) programs for all regions, in million mds

Sno	Commodity group	NP(1960-61) original	NP(1960-61) ± 10%		NP(1960-61) ± 20%		NP(1960-61) ± 40%	
			Quantity	%Inc[a]	Quantity	%Inc[a]	Quantity	%Inc[a]
1	Food grains	1876.7155	1904.4015	1.48	1933.4669	3.02	1990.1230	6.04
2	Sugarcane	210.0626	231.0648	9.99	231.0648	9.99	252.0671	19.99
3	Cotton	79.1604	85.3454	7.81	91.5601	15.66	103.9599	31.32
4	Jute	21.8779	24.0657	10.00	26.2535	20.00	30.6291	40.00
5	Oil seeds	164.9485	169.8937	3.00	176.6804	7.11	188.3862	14.21

[a]Percentage increase over original.

grains confirm the tendency exhibited by the corresponding gains in income. RP programs favor production of oil seeds at the cost of food grains. On the contrary, NP programs push food grains production to some extent by reducing oil seeds production. Comparisons between periods involving different production coefficients within RP or NP programs show that the relative increases in production of food grains are slightly higher for programs using 1960-61 production coefficients whereas in the case of programs using production coefficients pertaining to the 1957-61 period, the corresponding percentage for oil seeds is somewhat higher. It shows the 1957-61 production coefficients slightly swing the comparative advantage towards oil seeds as against food grains; on the contrary, programs using 1960-61 production show higher percentage increases for food grains and cotton as compared to those for 1957-61.

Other interesting features brought out by comparison of figures in Tables 18 - 21 and 22 - 25 are that the percentage gains in incomes through programming for food grains are higher by appreciable magnitudes than those noted in production. On the contrary, the rises expressed in percentages in production are higher for oil seeds as compared to those in incomes. The latter fact is more marked for oil seeds in the case of NP programs.

Incomes are based on production and prices. The comparatively higher percentage increases in incomes than those in production for food grains through programming are because on the whole, those food grains which are gainers in areas have relatively less yield (per acre) differentials over those losers in areas, than the corresponding price-differentials in those. It may not be true in all cases, but holds in general. The change in composition of food grains can be gauged from the tables in the Appendix. The gainers generally are rice and wheat and losing group comprises jowar, bajra, et cetera, the so-called inferior food grains. The higher percentage increases in incomes are thus indicative of the improvement in the composition of the bundle of food grains. The income gains are, therefore, more precise indicators of the efficiency of the programs than the increases in quantities.

As opposed to food grains, the percentage gains in production of oil seeds in different programs have surpassed the corresponding relative increases in incomes. It indicates that differences in yield per acre of oil seeds for which acreages have been pushed up in solutions of programs as against those for which such areas have gone down, are relatively higher than the corresponding price-gaps. The former category comprised of groundnut and rape and mustard for RP programs and groundnut only for NP programs, among the oil seeds. The remaining are losers in areas. The argument developed in the case of food grains that income levels are better indicators of the efficiency of the program may not hold true here. Relatively more gains in production than income for oil seeds does not necessarily mean that quality of the basket of the oil seeds has deteriorated to some extent. Different oil seeds are used for various industrial products, animal feeds, et cetera. Further, the gainers in areas are the two major oil seeds, groundnut and rape and mustard.

Distribution of areas among different groups of crops

It may be observed from Tables 26 - 29 that acreages under food grains progressively decrease with higher changes in areas of crops allowed in programs. All the remaining four groups share the areas released from food grains, so their areas increase correspondingly.

Comparing the RP programs using two sets of production coefficients, 1957-61 and 1960-61, it may be seen that the percentage distributions of areas are nearly the same. Food grains and cotton acreages are slightly more for RP(1960-61) as compared to RP(1957-61), in which case oil seeds acreages are higher.

As regards NP programs involving two sets of production coefficients, the distribution of acreages also compares fairly well. In this case, food grains and oil seeds have slightly higher proportion of areas in 1957-61 than in 1960-61. It is

Table 26. Distribution of acreages among different groups of crops for RP(1957-61) for all regions, in million acres

Sno	Commodity group	RP(1957-61) original		RP(1957-61) ± 10%		RP(1957-61) ± 20%		RP(1957-61) ± 40%	
		Area	%Dis[a]	Area	%Dis[a]	Area	%Dis[a]	Area	%Dis[a]
1	Food grains	229.805	79.81	227.1344	78.89	224.8765	78.10	219.9380	76.39
2	Sugar-cane	5.173	1.80	5.6903	1.98	5.6903	1.98	6.2076	2.16
3	Cotton	19.484	6.77	20.5789	7.15	21.6917	7.53	23.8994	8.30
4	Jute	1.717	0.60	1.8887	0.65	2.0604	0.72	2.4038	0.83
5	Oil seeds	31.732	11.02	32.6307	11.33	33.6041	11.67	35.4742	12.32

[a]Percentage distribution.

Table 27. Distribution of acreages among different groups of crops for NP(1957-61) for all regions, in million acres

Sno	Commodity group	NP(1957-61) original		NP(1957-61) ± 10%		NP(1957-61) ± 20%		NP(1957-61) ± 40%	
		Area	%Dis[a]	Area	%Dis[a]	Area	%Dis[a]	Area	%Dis[a]
1	Food grains	229.805	79.81	227.7989	79.13	225.9040	78.46	221.9930	77.10
2	Sugar-cane	5.173	1.80	5.6903	1.98	5.6903	1.98	6.2076	2.16
3	Cotton	19.484	6.77	20.6005	7.15	21.7309	7.54	23.9778	8.33
4	Jute	1.717	0.60	1.8887	0.65	2.0604	0.72	2.4038	0.83
5	Oil seeds	31.732	11.02	31.9446	11.09	32.5374	11.30	33.3408	11.58

[a]Percentage distribution.

Table 28. Distribution of acreages among different groups of crops for RP(1960-61) for all regions, in million acres

Sno	Commodity group	RP(1960-61) original		RP(1960-61) ± 10%		RP(1960-61) ± 20%		RP(1960-61) ± 40%	
		Area	%Dis[a]	Area	%Dis[a]	Area	%Dis[a]	Area	%Dis[a]
1	Food grains	229.805	79.81	227.3953	78.98	225.4606	78.30	221.1062	76.79
2	Sugar-cane	5.173	1.80	5.6897	1.98	5.6897	1.98	6.2064	2.16
3	Cotton	19.484	6.77	20.5993	7.15	21.7285	7.55	23.9730	8.33
4	Jute	1.717	0.60	1.8887	0.65	2.0604	0.72	2.4038	0.83
5	Oil seeds	31.732	11.02	32.3499	11.24	32.9838	11.45	34.2336	11.89

[a]Percentage distribution.

Table 29. Distribution of acreages among different groups of crops for NP(1960-61) for all regions, in million acres

Sno	Commodity group	NP(1960-61) original		NP(1960-61) ± 10%		NP(1960-61) ± 20%		NP(1960-61) ± 40%	
		Area	%Dis[a]	Area	%Dis[a]	Area	%Dis[a]	Area	%Dis[a]
1	Food grains	229.805	79.81	227.6152	79.06	225.5845	78.34	221.3540	76.88
2	Sugar-cane	5.173	1.80	5.6897	1.98	5.6897	1.98	6.2064	2.16
3	Cotton	19.484	6.77	20.9629	7.28	22.4557	7.80	25.4274	8.83
4	Jute	1.717	0.60	1.8887	0.65	2.0604	0.72	2.4038	0.83
5	Oil seeds	31.732	11.03	31.7666	11.03	32.1327	11.16	32.5314	11.30

[a]Percentage distribution.

balanced by somewhat higher proportion shown by cotton acreages in 1960-61. Using national prices has favored a little food grains in 1957-61 over 1960-61.

It may be interesting to compare RP and NP programs. As observed in the case of production and incomes, RP programs favor oil seeds acreages and NP programs food grains acreages in both periods. Cotton acreages are slightly improved in NP programs as compared to RP programs for 1957-61, but these increases are comparatively marked for programs using production coefficients for 1960-61.

It seems relevant to compare the contribution to total incomes from different groups (Tables 30 and 31) along with distribution of acreages. At the original situation nearly 80% of total cropped area under consideration is covered by food grains and the contribution to total income from it is about 74 per cent. Other groups contribute more to income than their proportions in areas. The most significant among these in this respect is sugarcane, followed by jute, cotton and oil seeds. This tendency is kept up in all the solutions of the programs, with the share of incomes decreasing from food grains with higher changes allowed for in crop areas. It may be of interest to know that whereas areas and production under cotton have experienced a small rise in NP(1957-61) programs over RP(1957-61) programs, the absolute income and its share to total income have not exhibited any such tendency.

Table 30. Percentage distribution of total income among different commodity groups

Sno	Commodity group	RP(1957-61)				NP(1957-61)			
		Original	± 10%	± 20%	± 40%	Original	± 10%	± 20%	± 40%
1	Food grains	74.17	73.24	73.00	71.96	74.16	73.43	73.29	
2	Sugarcane	9.07	9.65	9.40	9.70	9.07	9.66	9.42	
3	Cotton	6.11	6.25	6.44	6.73	6.11	6.25	6.44	
4	Jute	1.44	1.53	1.62	1.79	1.44	1.53	1.63	
5	Oil seeds	9.21	9.33	9.54	9.82	9.22	9.13	9.22	
6	Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	

Table 31. Percentage distribution of total areas among different crops

Sno	Commodity group	RP(1960-61)				NP(1960-61)			
		Original	± 10%	± 20%	± 40%	Original	± 10%	± 20%	± 40%
1	Food grains	74.68	73.76	73.53	72.49	74.57	73.75	73.52	72.59
2	Sugarcane	8.80	9.35	9.11	9.39	8.80	9.36	9.13	9.42
3	Cotton	6.86	7.05	7.28	7.66	6.82	7.11	7.43	7.98
4	Jute	1.38	1.46	1.55	1.71	1.38	1.47	1.56	1.72
5	Oil seeds	8.28	8.38	8.53	8.75	8.43	8.31	8.36	8.29
6	Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

In the case of NP(1960-61) programs, acres, productions and income of cotton do increase over RP(1960-61) programs. The magnitudes involved for RP(1957-61) and NP(1957-61) programs for cotton are, however, too small to draw any firm conclusion regarding these deviations.

Optimal cropping plans for different programs The consolidated national production plans for different programs are given in the tables in the Appendix.

It may be noted that the optimal cropping plans indicating crop acreages at national level compare more closely with one another for programs employing same price basis, but different production coefficients, rather than of those using same production coefficient but different price basis. It may be useful to note general deviations in cropping plans for programs using same production coefficient but different price basis. These are as follows.

The overall acreages under food grains as already mentioned are larger to some extent for NP programs than those for RP programs. Rice and ragi are mostly responsible for these larger acreages. The comparatively high acreages under rice and ragi in NP programs are to some extent counterbalanced by relatively more acreages of maize and barley in RP programs.

Sugarcane, cotton and jute, generally termed commercial crops, do not show any appreciable impact of difference in price basis.

Oil seed acreages, as pointed out earlier, are higher for RP programs than for NP programs. This is due mainly to comparatively more areas of groundnut and rape and mustard in RP programs.

Gross rents The gross overall rent per acre for different regions are given in Table 32 for RP(1957-61) ± 10%, along with specific rents for each crop $Y^L_{j(max)}$ and $Y^L_{j(min)}$. $Y^L_{j(max)}$ are positive and $Y^L_{j(min)}$ are negative. The rents for other programs are proposed to be presented along with regional plans later.

Main conclusions from program solutions

It may be useful to present in a consolidated form the major results that flowed out of programming the Indian agricultural economy.

1. Programming solutions increase over all income by about 3 per cent with ± 10% changes in areas, by about 6 per cent with ± 20% changes and by about 12 per cent with ± 40% changes. Neither the different price-basis, regional prices or national prices, nor the different sets of production coefficients, based on 1957-61 or 1960-61, make any significant differences in relative improvements in overall incomes of programs over the corresponding original ones.

Table 32. General rent (gross) per acre and specific rents per acre of different crops, in rupees, for RP(1957-61) ± 10% ($\gamma^L_{(min)}$ are negative and $\gamma^L_{(max)}$ are positive)

	Andra Pradesh	Assam	Bihar	Guzrat	Jamu and Kashmir
Rice	+162.319	0.000	0.000	- 10.443	+ 80.319
Jowar	- 46.075	-	-108.760	- 89.195	-
Bajra	- 47.868	-	-109.176	- 69.748	- 30.530
Maize	- 23.860	- 61.998	- 37.309	+ 11.337	0.000
Ragi	0.000	-	- 84.418	+ 7.596	-
Wheat	- 55.266	- 60.916	- 56.547	+ 19.461	- 5.328
Barley	- 86.916	-	- 90.508	- 23.934	- 49.153
Gram	- 67.649	+ 33.858	- 86.437	- 62.487	- 30.945
Sugar-cane	+1249.563	+668.262	+399.445	+846.668	+ 42.050
Cotton	- 65.775	- 44.735	- 87.427	0.000	+116.478
Jute	-	+282.587	+ 42.946	-	-
Ground-nut	+ 34.512	-	-	+ 1.043	-
Castor-seed	- 77.837	- 57.098	- 37.898	- 60.620	-
Sesamum	- 56.869	- 15.168	- 84.048	- 63.370	-
Rape and mustard	-	- 3.042	- 65.799	+ 40.166	+ 28.788
Linseed	- 84.523	-	-107.234	-	+ 21.140
General rent	114.150	129.666	155.582	119.612	112.548

Table 32. (Continued)

	Kerala	Madhya Pradesh	Madras	Maha-rashtra
Rice	0.000	+37.528	+76.772	+85.741
Jowar	-102.726	-15.350	-118.916	0.000
Bajra	-	-27.919	-140.601	-28.656
Maize	-	-22.200	-90.015	-2.470
Ragi	+43.012	-61.299	-93.759	+32.173
Wheat	-	0.000	-60.997	+11.011
Barley	-	-0.913	-	+1.558
Gram	-	-19.827	-140.557	-22.051
Sugarcane	+512.773	+419.396	+833.157	+1227.737
Cotton	-1.074	-5.145	-36.589	+19.448
Jute	-	-	-	-
Groundnut	+16.735	+2.710	0.000	+48.484
Castorseed	-	-36.471	-135.953	-21.283
Sesamum	-103.208	-56.627	-118.403	+2.811
Rape and mustard	-	-14.657	-	+39.373
Linseed	-	-59.049	-	-24.387
General rent (gross)	187.380	101.399	216.015	74.984

Table 32. (Continued)

	Mysore	Orissa	Punjab	Rajasthan
Rice	+208.474	0.000	+9.053	+167.207
Jowar	-15.032	-73.494	-91.049	-10.497
Bajra	-41.152	-111.601	-73.082	-17.587
Maize	+39.075	-87.385	+58.264	+63.438
Ragi	+33.129	-88.764	-72.625	-
Wheat	-16.384	-22.953	+59.826	+111.785
Barley	+11.846	-	-7.574	+101.856
Gram	-20.878	-107.732	-12.160	+29.335
Sugarcane	+1199.797	+461.982	+407.160	+356.790
Cotton	0.000	-104.460	+155.369	+76.614
Jute	-	+101.703	-	-
Groundnut	+56.073	-27.675	+20.156	+57.187
Castorseed	-10.537	-105.661	-	+68.442
Sesamum	-10.914	-87.914	-33.939	0.000
Rape and mustard	+17.578	-39.330	0.000	+51.705
Linseed	-26.746	-90.349	-40.039	+6.357
General rent (gross)	68.007	146.360	113.631	49.692

Table 32. (Continued)

	Uttar Pradesh	West Bengal	Delhi	Himachel Pradesh
Rice	-19.529	0.000	+262.716	+59.014
Jowar	-25.158	-157.097	-30.187	-
Bajra	-23.344	-	0.000	-
Maize	0.000	-117.472	+48.759	-19.041
Ragi	-33.898	-149.490	-	-84.609
Wheat	+45.392	-129.333	+62.510	0.000
Barley	+6.533	-164.150	-42.503	-85.770
Gram	-14.364	-144.796	-18.283	-81.684
Sugarcane	+415.014	+607.283	+179.118	+133.245
Cotton	+17.550	-	-	-
Jute	+136.248	+106.679	-	-
Groundnut	+34.847	-	-	-
Castorseed	-16.064	-	-	-
Sesamum	-44.790	-92.663	-	-
Rape and mustard	+19.281	-128.618	-	-66.611
Linseed	-37.193	-177.646	-	-
General rent (gross)	96.280	222.643	71.978	150.708

2. Programs involving regional prices favor the production of oil seeds to some extent as compared to food grains. On the contrary, programs employing national prices do enhance acreages and production of food grains and cotton to some extent at the cost of acreage and production of oil seeds.
3. Overall income from food grains in all programs increases at a faster rate than that of production. It indicates the improvements in the composition of food basket. The acreages and ultimately the production of comparatively superior food grains have increased.
4. In the case of oil seeds relative increases in production in programs are higher than the respective improvements in incomes. It need not be taken as deterioration in the composition of oil seeds production when other facts are taken into account.
5. Programs involving national prices and combining 1960-61 production coefficient show comparatively more marked improvements in production and income of cotton than those for other programs. The year 1960-61 was favorable to production of cotton.
6. Contributions of food grains covering the largest proportion of areas, 72% - 80%, to total incomes are less than their relative shares in areas. The other groups contribute more to total income than their proportions

in total area. This is true for all program solutions.

7. Resulting national plans (indicating acreage under individual crops) from programs having different coefficients but the same price-basis compare more closely with one another as compared to those having same production coefficient but different price-basis. The use of regional prices and national prices also does not seem to have resulted in marked differences in optimal plans of programs. Regional prices thus quite closely approach the competitive level of prices.
8. The increases in the programs in no commodity group surpass the targets planned for the third plan mentioned in Chapter II. The potentialities of this policy instrument--making desirable shifts in crop acreages--are quite significant and thus need to be considered for policy purposes.

VIII. SUMMARY

The foremost aim of the present study is to examine potentialities and applicability of certain inter-regional models for agricultural development planning in India. To provide a necessary background for the study, progress made in agricultural development during a decade of planning in India is briefly stated in Chapter II. The prospects for the third five year plan, initiated since 1961, are also included therein.

A number of policy models have been suggested for planning in India. Professor Mahalanobis' model was one of these such models considered in framing the second five year plan. Hence, it appears appropriate to examine some of these models and assess their relevance to the requirements of agriculture planning. Chapter III is devoted to this purpose. These models are of macro nature and none incorporates the regional aspect of planning. Review of these models, achievements during the decade of planning, and policy instruments employed to attain those achievements shows that inter-regional analysis has not been given its due place in planning.

Inter-regional analysis has caught the attention of quite a number of eminent research workers in the last two decades. A number of regional studies have been attempted, with varying objectives. Some of these are directed towards arriving at equilibrium prices of certain commodities in different markets, while some others laid emphasis on finding out optimal allocation of resources. In order to take advantage of the theoretical framework of these studies and of results flowing from them, in the pursuits of the present investigations, some of the relevant among the above-mentioned studies are reviewed in Chapter IV.

The main task of the study begins with developing an inter-regional linear programming model for agricultural development planning in Chapter V. The objective of the model is to maximize net income of regions from agriculture, and subsequently of the country as a whole from agriculture, taking into account inter-regional flows of commodities with given transport facilities. Resource supplies are given and minimum requirements of certain commodities in different regions are known. Leaving out the transport restriction from the model gives the total requirements of transport facilities at the optimum solution. This information is important in planning for the transport facilities.

Important results flow from incorporating regional availability constraints of certain goods in the model. These restrictions yield subsidy prices, adjustment factors for prices of goods in different regions, known of the model. It is interesting to note that though prices of goods are taken as known in the beginning, the competitive level of prices for those goods for which regional constraints are incorporated in the model are a part of the solution. The original prices of commodities are adjusted by adding to those corresponding subsidy prices. Accounting prices of intermediate goods and of resources in different regions are also generated by the model. These are often very badly needed for planning purposes.

The model fairly meets the characteristics of the inter-regional general equilibrium system so far as agricultural sector is concerned. The adjusted prices of commodities are allowed to differ in a pair of regions by the transport cost only. Similarly, returns to mobile resources in a pair of regions can differ by transport cost of a resource from one to another region.

It may be pointed out that it is not a complete dynamic general equilibrium model for agricultural sector. But taking prices of commodities as given, and making adjustments in consumptions, incomes and resource supplies of regions outside the model, it fairly meets the characteristics of the one point equilibrium system. Regional demand functions of commodities are not a part of the model. However, it has been shown that making adjustments in the approach of Yaron and Heady (1961) to nonlinear programming, regional demand functions can easily be included in the model. The aforesaid approach of Yaron and Heady ends with the monopolistic situation, but the adjusted one is consistent with competitive economy.

Requirements of data for running the aforesaid general model are quite extensive. Some operational models from the general model are generated in Chapter VI to meet the limited objectives. These models are of particular significance for practical purposes. Models E and F need special mention in this connection. Model E mainly aims at attaining optimal land allocation among different crops. The transportation and other resource restrictions are excluded from it. Model F is for optimum allocation of a resource on a given land use pattern in different regions.

Investment allocation is a crucial factor in development planning. Different criteria of investment have been discussed in second parts of Chapter VI. A linear programming criterion for investment allocation is developed. It minimizes the capital cost to meet the specified demands of the commodities consistent with the availability of other factors of production and other commodity inputs. An important feature of the investment allocation model is that a project can be run at different ranges. It is of particular relevance for major irrigation projects, which can be built at different levels. An integer programming technique is employed in this model to eliminate the possibility of occurrence of more than one stage of the same project in the final solution.

Linear programming criterion of investment is equivalent to benefit-cost ratio of commodities and factors are valued at the opportunity cost in terms of capital. Social marginal productivity criterion and linear programming criterion will give identical results if the same accounting prices are used. Linear programming criterion does not require that marginal productivity of capital should be known. It generates the accounting prices and balances supply and demand of different commodities and factors of production. The most important thing in the operation of the model is to specify correctly what amount of quantities of different commodities are required to be produced and what amount of resources are available.

Chapter VII is devoted to empirical analysis. It revolves around the inter-regional linear programming model for land use planning. Model E developed in Chapter VI has been adjusted in accordance with the availability of data for this purpose. The model, set up for programming, purposes to maximize gross income from agriculture sector of the economy. It does not allow regional incomes to fall lower than those already obtained, and does not permit production of food grains, sugarcane, cotton, jute and oil seeds to go below the levels reached earlier for the country as a whole. The reallocation of land among crops in a region is kept within specified limits. It has been argued that maximizing gross income or net income would not change the results substantially as a very small proportion of inputs is monetised. The programming results will show how much agricultural production could be increased through land use planning only.

The model has 467 restrictions and 214 activities. The country has been divided into 17 regions. In each region 16 crops (eight food grains, five oil seeds, sugarcane, cotton and jute) form the crop production coverage of the model. All these 16 crops taken together comprise more than 77 per cent of cropped area annually in the country. Among 467 restrictions, there are 17 regional restrictions, each for cropped area of a region and minimum income levels specified for a region. Each of the aforesaid crops have maximum and minimum area limits in each region. Such restrictions are 228 in number, one set among these is formed by 214 minimum acreages restrictions for crops, another set equal in number is comprised by maximum acreages restrictions of crops. Further the system includes 5 availability restrictions at national level; one constraint is for each of five groups of crops, namely, food grains, sugarcane, cotton, jute and oil seeds. All the crops are not grown in each region. The total number of activities thus comes to 214 instead of 272 (17 x 16).

Two sets of production coefficients pertaining to 1956-57 to 1960-61, the second plan period, and relating to 1960-61, the base year for the third plan, are employed.

There are two sets of prices used as well. One set is of regional prices and the second one of national prices. The programs using the former set result in reallocation of land among different crops due to differential yields and differential prices in various regions. The impact of the differences in prices of the same commodity in various regions on reallocation of land is eliminated in programs using national prices. The main results from programming, in brief, are as follows.

1. On the whole ± 10% changes in each crop area lead to about 3% increases in income over the corresponding original figures, ± 20% changes raise this increase to 6% and ± 40% adjustments in acreages further enhance this improvement in incomes to about 12%.
2. Neither the different price bases used, nor the different sets of production coefficients employed in the model, make significant differences in improvements in incomes. The regional set of prices thus is fairly indicative of the competitive nature of the economy.
3. Programs involving regional prices favor production of oil seeds as compared to food grains. The reverse is the case for programs using national prices.
4. Percentage increases in production in the case of food grains are greater than experienced in incomes from food grains. The area and production of superior food grains

has increased. It shows improvement in the composition of food grains basket.

5. Food grains group covers about 72 - 80% of the total cropped area. The improvements in production of this group are at minimum level as compared to those for other groups. Of the remaining groups, jute and sugarcane show the maximum possible increases in production allowed by changes in areas. Cotton is the third in order, followed by oil seeds.

6. Resulting national plans (indicating acreages under individual crops) from programs having different coefficients but the same price-bases compare more closely with one another as compared to those having the same production coefficients but different price bases.

Land use planning can play a significant role in meeting targets of five year plans. This powerful instrument of planning needs to be given a serious thought by research workers, planners, and administrators.

IX. LITERATURE CITED

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XXI. APPENDIX

Table 33. Cropping plan at national level for RP(1957-61) original (units in millions)

Crop	Optimal area Acres	Production Mds[a]	Income Rs
Rice	80.464000	800.030610	14059.191000
Jowar	41.835000	224.740030	2758.384300
Bajra	27.569000	91.388791	1265.302400
Maize	10.204000	94.633026	1147.993700
Ragi	5.856000	48.090636	585.034600
Wheat	31.631000	258.702360	4128.916800
Barley	8.147000	71.533677	853.456240
Gram	24.099000	161.677770	1996.827700
Total food	229.805000	1750.796500	26795.103000
Sugarcane	5.173000	202.254680	3277.764300
Cotton	19.484000	66.258489	2208.058900
Jute	1.717000	21.252053	518.901170
Groundnut	14.688000	118.948000	2037.191400
Castor	1.218000	2.889352	57.682944
Sesamum	5.253000	10.565189	299.091990
Rape and mustard	6.521000	29.372013	730.585560
Linseed	4.052000	10.462321	201.555410
Total oils	31.732000	172.236860	3326.107100
Regional total	287.911000		36125.930000

[a]26.792 Maunds = 1 metric ton.

Table 34. Cropping plan at national level for RP(1957-61) ± 10% (units in millions)

Crop	Optimal area Acres	Production Mds[a]	Income Rs
Rice	82.999906	832.684150	14718.554000
Jowar	38.118502	205.091940	2517.559000
Bajra	24.818200	82.280377	1139.211100
Maize	10.338003	96.697214	1171.782000
Ragi	6.014700	49.688704	605.385340
Wheat	33.898703	279.616020	4459.080400
Barley	8.518699	75.681713	902.795800
Gram	22.427699	150.473440	1855.581600
Total food	227.134380	1772.213300	27369.947000
Sugarcane	5.690299	222.480100	3605.540300
Cotton	20.578904	70.049165	2337.286400
Jute	1.888700	23.377257	570.791280
Groundnut	15.901298	127.558380	2186.827900
Castor	1.097000	2.605861	52.009152
Sesamum	5.019603	10.055332	285.763840
Rape and mustard	6.906199	31.199644	776.376400
Linseed	3.706600	9.584727	185.031100
Total oils	32.630700	181.003930	3486.008300
Regional total	287.922950		37369.570000

[a]26.792 Maunds = 1 metric ton.

Table 35. Cropping plan at national level for RP(1957-61) ± 20% (units in millions)

Crop	Optimal area Acres	Production Mds[a]	Income Rs
Rice	85.594304	865.849550	15387.372000
Jowar	34.428401	185.604360	2278.721900
Bajra	22.068500	73.177462	1013.199100
Maize	10.558701	99.480323	1203.906100
Ragi	6.188299	51.424925	627.436800
Wheat	36.177403	300.603480	4790.374100
Barley	8.890400	79.829769	952.135620
Gram	20.970505	140.710710	1731.874500
Total food	224.876490	1796.680300	27985.017000
Sugarcane	5.690299	222.480100	3605.540300
Cotton	21.691702	73.886111	2467.937000
Jute	2.060400	25.502462	622.681400
Groundnut	17.126598	136.325710	2339.057000
Castor	0.976000	2.322370	46.335365
Sesamum	4.793902	9.557914	272.818140
Rape and mustard	7.346400	33.286612	828.417200
Linseed	3.361200	8.707132	168.506800
Total oils	33.604100	190.199720	3655.134400
Regional total	287.922970		38336.308000

[a]26.792 Maunds = 1 metric ton.

Table 36. Cropping plan at the national level for RP(1957-61) ± 40% (units in millions)

Crop	Optimal area Acres	Production Mds[a]	Income Rs
Rice	90.719600	931.618520	16714.797000
Jowar	27.021802	146.468690	1799.059800
Bajra	16.568000	54.966139	761.096050
Maize	10.912401	104.318340	1259.705700
Ragi	6.516600	54.722148	669.382650
Wheat	40.723804	342.504600	5451.831100
Barley	9.633801	88.125872	1050.814900
Gram	17.842000	119.743570	1466.920600
Total food	219.938000	1842.467600	29173.604000
Sugarcane	6.207600	242.705600	3933.317300
Cotton	23.899401	81.513748	2727.815100
Jute	2.403799	29.752859	726.461320
Groundnut	19.563200	153.677290	2640.491200
Castor	0.734000	1.755387	34.987791
Sesamum	4.334802	8.550637	246.544200
Rape and mustard	8.171800	37.201214	926.248850
Linseed	2.670400	6.951944	135.458180
Total oils	35.474202	208.136450	3983.730000
Regional total	287.922990		40544.925000

[a]26.792 Maunds = 1 metric ton.

Table 37. Cropping plan at the national level for NP(1957-61) original (units in millions)

Crop	Optimal area Acres	Production Mds[a]	Income Rs
Rice	80.464000	800.030610	14062.633000
Jowar	41.835000	224.740030	2757.296000
Bajra	27.569000	91.388791	1265.679400
Maize	10.204000	94.633026	1147.739700
Ragi	5.856000	48.090636	584.956960
Wheat	31.631000	258.702360	4165.204700
Barley	8.147000	71.533677	853.734940
Gram	24.099000	161.677770	1960.878500
Total food	229.805000	1750.796500	26798.119000
Sugarcane	5.173000	202.254680	3277.864700
Cotton	19.484000	66.258489	2208.259600
Jute	1.717000	21.252053	519.252110
Groundnut	14.688000	118.948000	2038.557800
Castor	1.218000	2.889352	57.688318
Sesamum	5.253000	10.565189	302.323090
Rape and mustard	6.521000	29.372013	730.565540
Linseed	4.052000	10.462321	201.559700
Total oils	31.732000	172.236860	3330.694300
Regional total	287.911000		36134.186000

[a]26.792 Maunds = 1 metric ton.

Table 38. Cropping plan at the national level for NP(1957-61) ± 10% (units in millions)

Crop	Optimal area Acres	Production Mds[a]	Income Rs
Rice	85.232906	848.760620	14919.192000
Jowar	38.626301	208.165140	2553.938900
Bajra	24.818200	82.280377	1139.533500
Maize	9.854700	92.685800	1124.121800
Ragi	6.012100	49.650599	603.932160
Wheat	33.233104	276.205630	4447.012900
Barley	7.594700	67.642463	807.294540
Gram	22.426899	150.467990	1824.926400
Total food	227.798890	1775.858200	27419.948000
Sugarcane	5.690299	222.480100	3605.650600
Cotton	20.600503	70.122607	2337.042400
Jute	1.888700	23.377257	571.177300
Groundnut	15.868500	127.321580	2182.066800
Castor	1.097000	2.605861	52.028183
Sesamum	4.954803	9.875669	282.593590
Rape and mustard	6.317700	28.438995	707.358720
Linseed	3.706600	9.584727	184.652680
Total oils	31.944603	177.826810	3408.699700
Regional total	287.922980		37342.514000

[a]26.792 Maunds = 1 metric ton.

Table 39. Cropping plan at the national level for NP(1957-61) ± 20% (units in millions)

Crops	Optimal area Acres	Production Mds[a]	Income Rs
Rice	90.060303	898.002490	15784.747000
Jowar	35.444001	191.750770	2352.550800
Bajra	22.068500	73.177462	1013.463700
Maize	9.504701	90.732123	1100.425700
Ragi	6.183099	51.348714	624.587630
Wheat	34.846203	293.782690	4730.009200
Barley	7.042400	63.751252	760.854110
Gram	20.754800	139.258250	1688.974600
Total food	225.903990	1801.803400	28055.609000
Sugarcane	5.690299	222.480100	3605.650600
Cotton	21.730901	74.019146	2466.905000
Jute	2.060400	25.502462	623.102500
Groundnut	17.065000	135.879030	2328.726200
Castor	0.976000	2.322370	46.368051
Sesamum	4.664302	9.198585	263.220010
Rape and mustard	6.470905	29.179665	725.781800
Linseed	3.361200	8.707132	167.745680
Total oils	32.537407	185.286760	3531.841600
Regional total	287.922980		38283.106000

[a]26.792 Maunds = 1 metric ton.

Table 40. Cropping plan at the national level for NP(1957-61) ± 40% (units in millions)

Crop	Optimal area Acres	Production Mds[a]	Income Rs
Rice	99.651602	995.924430	17505.980000
Jowar	29.053002	158.761520	1947.805600
Bajra	16.568000	54.966139	761.248040
Maize	8.804401	86.821964	1052.999400
Ragi	6.506200	54.569725	663.767390
Wheat	38.061404	328.863010	5294.813700
Barley	5.937800	55.968831	667.973260
Gram	17.410600	116.838720	1417.070500
Total food	221.993000	1852.714100	29311.655000
Sugarcane	6.207600	242.705600	3933.437792
Cotton	23.977800	81.779821	2725.550900
Jute	2.403799	29.752879	726.952630
Groundnut	19.440000	152.783910	2618.446900
Castor	0.734000	1.755387	35.047787
Sesamum	4.075602	7.831977	224.116910
Rape and mustard	6.420800	28.987273	720.996910
Linseed	2.670400	6.951944	133.931630
Total oils	33.340802	198.310470	3732.540000
Regional total	287.922990		40430.130792

[a]26.792 Maunds = 1 metric ton.

Table 41. Cropping plant at the national level for RP(1960-61) original (units in millions)

Crop	Optimal area Acres	Production Mds[a]	Income Rs
Rice	80.464000	874.051160	15420.562000
Jowar	41.835000	241.472260	2966.785900
Bajra	27.569000	86.617094	1194.778300
Maize	10.204000	98.546148	1192.436900
Ragi	5.856000	44.829204	545.905270
Wheat	31.631000	284.651870	4539.126400
Barley	8.147000	75.948504	905.542270
Gram	24.099000	170.599520	2112.265300
Total food	229.805000	1876.715500	28877.399000
Sugarcane	5.173000	210.062620	3402.732900
Cotton	19.484000	79.160408	2652.616900
Jute	1.717000	21.877919	531.711410
Groundnut	14.688000	111.258540	1911.232900
Castor	1.218000	2.363624	47.024712
Sesamum	5.253000	8.141876	229.024180
Rape and mustard	6.521000	32.745987	814.049040
Linseed	4.052000	10.438574	200.809650
Total oil	31.732000	164.948580	3202.140300
Regional total	287.911000		38666.596000

[a]26.792 Maunds = 1 metric ton.

Table 42. Cropping plan at the national level for RP(1960-61) ± 10% (units in millions)

Crop	Optimal area Acres	Production Mds[a]	Income Rs
Rice	82.969605	907.492290	16101.637000
Jowar	38.856004	225.033000	2765.553400
Bajra	24.812100	77.955381	1075.300400
Maize	10.172100	99.834077	1203.284900
Ragi	5.922100	45.457728	554.400200
Wheat	33.230904	304.533780	4845.119200
Barley	8.516699	80.633724	961.219000
Gram	22.915902	162.534080	2010.452400
Total food	227.395390	1903.473600	29516.964000
Sugarcane	5.689699	231.064830	3742.937100
Cotton	20.599303	84.090668	2821.721900
Jute	1.888700	24.065709	584.882550
Groundnut	15.874299	118.923570	2045.073900
Castor	1.098200	2.139050	42.529062
Sesamum	4.731500	7.349120	206.662920
Rape and mustard	6.939300	35.099009	872.702140
Linseed	3.706600	9.569389	184.490820
Total oil	32.349899	173.080110	3351.458700
Regional total	287.922970		40017.96000

[a]26.792 Maunds = 1 metric ton.

Table 43. Cropping plan at the national level for RP(1960-61) ± 20% (units in millions)

Crop	Optimal area Acres	Production Mds[a]	Income Rs
Rice	85.588704	942.096210	16800.287000
Jowar	35.911103	208.807830	2566.971200
Bajra	22.055200	69.293672	955.822720
Maize	10.138900	101.109030	1213.975100
Ragi	6.003099	46.204730	564.353600
Wheat	34.841804	324.491850	5152.277800
Barley	8.886400	85.318967	1016.895800
Gram	22.035405	156.769530	1936.488000
Total food	225.460590	1934.091500	30207.068000
Sugarcane	5.689699	231.064830	3742.937100
Cotton	21.728501	89.050637	2[illegible]91.692700
Jute	2.060400	26.253501	638.053690
Groundnut	17.076599	126.771210	2181.969100
Castor	0.978400	1.914475	38.033417
Sesamum	4.210000	6.556365	184.301660
Rape and mustard	7.357600	37.452034	931.355250
Linseed	3.361200	8.700204	168.171990
Total oil	32.983799	181.394270	3503.831200
Regional total	287.922970		41083.579000

[a]26.792 Maunds = 1 metric ton.

Table 44. Cropping plan at the national level for RP(1960-61) ± 40% (units in millions)

Crop	Optimal area Acres	Production Mds[a]	Income Rs
Rice	90.708401	1010.087400	18179.174000
Jowar	29.987204	176.143420	2167.156200
Bajra	16.541400	51.970254	716.867040
Maize	10.072802	103.661950	1235.392100
Ragi	6.146200	47.548467	582.410550
Wheat	38.052603	364.331810	5765.428800
Barley	9.625801	94.689443	1128.249600
Gram	19.971800	142.939460	1760.709900
Total food	221.106200	1991.371900	31535.385000
Sugarcane	6.206400	252.067100	4083.142500
Cotton	23.973000	98.940883	3330.768800
Jute	2.403799	30.629071	744.395610
Groundnut	19.463201	142.257920	2452.276800
Castor	0.738800	1.465326	29.042127
Sesamum	3.167000	4.970854	139.579150
Rape and mustard	8.194199	42.158079	1048.661200
Linseed	2.670400	6.961835	135.534310
Total oils	34.233600	197.813990	3805.093500
Regional total	287.922980		43498.782000

[a]26.792 Maunds = 1 metric ton.

Table 45. Cropping plan at the national level for NP(1960-61) original (units in millions)

Crop	Optimal area Acres	Production Mds[a]	Income Rs
Rice	80.464000	874.051160	15370.614000
Jowar	41.835000	241.472260	2962.710800
Bajra	27.569000	86.617094	1199.675800
Maize	10.204000	98.546148	1195.206700
Ragi	5.856000	44.829204	545.257360
Wheat	31.631000	284.651870	4583.163700
Barley	8.147000	75.948504	906.448030
Gram	24.099000	170.599520	2069.101400
Total food	229.805000	1876.715500	28832.174000
Sugarcane	5.173000	210.062620	3404.405100
Cotton	19.484000	79.160408	2637.942700
Jute	1.717000	21.877919	534.539870
Groundnut	14.688000	111.258540	1906.743400
Castor	1.218000	2.363624	47.202904
Sesamum	5.253000	8.141876	232.973080
Rape and mustard	6.521000	32.745987	814.456720
Linseed	4.052000	10.438574	259.607980
Total oil	31.732000	164.948580	3260.983900
Regional total	287.911000		38670.041000

[a]26.792 Maunds = 1 metric ton.

Table 46. Cropping plan at the national level for NP(1960-61) ± 10% (units in millions)

Crop	Optimal area Acres	Production Mds[a]	Income Rs
Rice	84.984106	923.645680	16243.056000
Jowar	38.856004	225.033000	2761.009900
Bajra	24.812100	77.955381	1079.708300
Maize	10.228701	100.455670	1218.365700
Ragi	5.899101	45.219098	549.997660
Wheat	32.807504	301.571180	4855.579400
Barley	7.594700	71.657791	855.238780
Gram	22.432999	158.864250	1926.770700
Total food	227.615200	1904.401500	29489.722000
Sugarcane	5.689699	231.064830	3744.780000
Cotton	20.962903	85.345427	2844.047300
Jute	1.888700	24.065709	587.993850
Groundnut	15.894698	119.060370	2040.452100
Castor	1.097000	2.132620	42.589608
Sesamum	4.727700	7.327688	209.675750
Rape and mustard	6.315200	31.728064	789.137840
Linseed	3.732000	9.645005	239.871470
Total oils	31.766598	169.893730	3321.726600
Regional total	287.923080		39988.266000

[a]26.792 Maunds = 1 metric ton.

Table 47. Cropping plan at the national level for NP(1960-61) ± 20% (units in millions)

Crop	Optimal area Acres	Production Mds[a]	Income Rs
Rice	89.562704	973.822740	17125.737000
Jowar	35.911103	208.807830	2561.935700
Bajra	22.055200	69.293672	959.740780
Maize	10.252100	102.352190	1241.367100
Ragi	5.997899	46.119008	560.941640
Wheat	33.995004	318.566660	5129.221300
Barley	7.042400	67.367083	804.029550
Gram	20.768100	147.138190	1784.551400
Total food	225.584490	1933.466900	30167.521000
Sugarcane	5.689699	231.064830	3744.780000
Cotton	22.455701	91.560154	3051.142000
Jute	2.060400	26.253501	641.447830
Groundnut	17.076599	126.771210	2172.601300
Castor	0.976000	1.901616	37.976317
Sesamum	4.202400	6.513501	186.378460
Rape and mustard	6.465705	32.642683	811.885020
Linseed	3.412000	8.851436	220.134960
Total oils	32.132704	176.680430	3428.975900
Regional total	287.922970		41033.864000

[a]26.792 Maunds = 1 metric ton.

Table 48. Cropping plan at the national level for NP(1960-61) ± 40% (units in millions)

Crop	Optimal area Acres	Production Mds[a]	Income Rs
Rice	98.656400	1073.540400	18879.915000
Jowar	29.987204	176.143240	2161.160500
Bajra	16.541400	51.970254	719.805570
Maize	10.299203	106.148280	1287.407000
Ragi	6.135800	47.377023	576.239160
Wheat	36.359003	352.481440	5675.278300
Barley	5.937800	58.785664	701.611080
Gram	17.437200	123.676860	1500.001300
Total food	221.354000	1990.123000	31501.416000
Sugarcane	6.206400	252.067100	4085.155800
Cotton	25.427400	103.959910	3464.341200
Jute	2.403799	30.629071	748.355490
Groundnut	19.463201	142.257920	2438.015000
Castor	0.734000	1.439608	28.749732
Sesamum	3.151800	4.885126	139.783840
Rape and mustard	6.410400	32.539328	809.312020
Linseed	2.772000	7.264298	180.661940
Total oils	32.531401	188.386250	3596.522400
Regional total	287.922990		43395.787000

[a]26.792 Maunds = 1 metric ton.